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THE
GEOLOGICAL MAGAZINE
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No. I.—JANUARY, 1931.

ORIGINAL ARTICLES.

The Geology of the Farsan Islands, Oizan and Kamaran Island, Red Sea.

(Continued from Vol. LXVII, p. 315.)

Part 2.—Molluscan Palaeontology.

By L. R. Cox, M.A., F.G.S.[1]

I. General Discussion.

THE collection of mollusca dealt with in this paper was made by Dr. W. A. Macfadyen during his survey of the Farsan Islands, Kamaran Island, and the adjacent Arabian coast in the winter 1926–7. An account of the geology has been given by him in Part 1 of the paper, while Mr. A. G. Brighton will be contributing a section on the fossil echinoids. Dr. Macfadyen's investigation has shown that the islands are composed mainly of fossiliferous strata of late Cainozoic age. It was found possible to make out a definite succession, broken by local unconformities, and a good collection of fossils was made from each stratigraphical subdivision in the hope that definite evidence of the age of the beds would be obtained. The only previous contribution to the palaeontology of the area is a paper by Jousseaume (1888),[2] which includes an account of twenty-five species of "raised beach" mollusca collected by Faurot on Kamaran Island. One of these —a *Spondylus*—is described as new, but the remainder are referred to living Indo-Pacific species. It appears from Faurot's description (1888, p. 534) that these shells came from the top bed of the Reef Limestone of Dr. Macfadyen's classification. Lists of the species present in Dr. Macfadyen's collection are given in the second part of the present paper, but these will be preceded by a short discussion of the general results of the investigation, and also of our present knowledge of the molluscan fauna of the late Cainozoic deposits of the Erythraean region.

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[1] Published by permission of the Trustees of the British Museum.

[2] See the bibliography at the end of this paper.

This latter subject and its bearing upon problems connected with the history of the Red Sea have already been discussed by me (1929) in a paper dealing with the Ostreidae and Pectinidae of the region. Fossiliferous Miocene rocks containing a Mediterranean fauna are well developed in the Gulf of Suez area, and were evidently deposited in a gulf of the Mediterranean Ocean. There is no evidence either from published information or from the collection now studied that this gulf extended so far south as the latitude of the Farsan Islands. The fossiliferous Miocene rocks are succeeded by a great thickness of gypsum and salt deposits, which in turn are overlain by marine fossiliferous rocks of late Cainozoic age. The view advanced in Dr. W. F. Hume's *Report on the Oilfields Region of Egypt* (1916) is that the earliest post-Gypsum beds (the so-called " Plio-Miocene " series) still contain a Mediterranean fauna of Miocene affinities, and are separated by a very significant unconformity from the " Plio-Pleistocene " beds with an Indo-Pacific fauna. In my paper, however, I showed that the supposed Mediterranean Miocene element could be interpreted equally well as a more modern Indo-Pacific element, and that there is no fundamental difference between the fauna of the " Plio-Miocene " beds and that of the overlying " Plio-Pleistocene ". This view was based mainly on the Ostreidae and Pectinidae present in these deposits, but it has since been confirmed by study of a good series of molluscan fossils collected by Mr. R. H. Mitchell from the " Plio-Miocene " of Towila Island, and presented to the British Museum. Although mostly internal casts, many of these specimens can be determined without difficulty, and have been found to include such characteristic Indo-Pacific species as *Arca tortuosa* Linn., *Barbatia lacerata* (Brug.), *Chlamys senatoria* (Gmel.), *Paphia literata* (Linn.), and the extinct form, *Pecten vasseli* Fuchs. The significance of the presence in these cast beds of the two species *Diplodonta rotundata* (Mont.) and *Apolymetis papyracea* (Gmel.) [*Tellina lacunosa* Chemn.], well known as Mediterranean Miocene forms, seems to have been over-emphasized by previous writers. Both Mr. Mitchell's collection and that now studied show that both these species range throughout the post-Miocene deposits of the region and are not restricted to the basal beds. They are, in fact, still living in the Erythraean province, although apparently in less abundance than in former times. There can therefore be no doubt that the " Plio-Miocene " and " Plio-Pleistocene " belong to one series of deposits, broken only by local unconformities. I suggest that these terms would be best abandoned in favour of Barthoux's term " Erythraean " Series (1922, p. 104).

The precise period of geological time represented by these beds remains, however, to be determined. As already mentioned, many of the fossils are obviously referable to Indo-Pacific species living at the present day ; the general state of preservation, however, is so unsatisfactory that a very much larger series of specimens than is at present available will have to be studied before any definite decision can be reached as to what proportion of the fauna is extinct. Of the few easily recognized extinct species that range throughout the series, two of the most important are the bivalves *Pecten vasseli* Fuchs and *Ostrea tridacnaeformis* Cox. Now, recent work (Cox, 1927 and 1930) has shown that in East Africa these are two of the most characteristic species of the Pliocene, while they have not yet been found in any of the Pleistocene deposits of that coast, although good collections have now been made from the beds in question. The supposed Pleistocene *Pecten vasseli* beds of Tanga have now been shown to be considerably older than the Reef Limestones of Dar-es-Salaam with which they were at first correlated, and to belong to the Pliocene (Stockley, 1929). Hence the presence of these two species in the deposits of the Erythraean Series seems to indicate that this series is, for the greater part at least, pre-Pleistocene in age. In my previous paper I suggested that it may represent the whole of Pliocene time, but, from the further material now examined, I am inclined to regard the whole series as somewhat younger than the beds of Zanzibar and Mombasa, the age of which seems to be Lower to Middle Pliocene. Thus the species *Chlamys werthii* (Phil.), *Ch. bornhardti* Cox, and *Spondylus insularis* Cox, which are as characteristic of the East African Pliocene as are the two forms already mentioned, have not yet been found in the Erythraean region; their places are, however, taken by *Chlamys lessepsii* (Fuchs), *Ch. isthmica* (Fuchs), and *Ch. leesi* Cox, species unknown in East Africa. The first three species have now been found so far from their type-locality as northern Ceylon, while *Ch. lessepsii* has been found in Persia as well as in the Erythraean region, showing that all these forms had a fairly wide distribution. The conclusion is, therefore, that these two groups of species correspond to slightly different periods, the first group possibly to Lower-Middle Pliocene, the second group to Middle-Upper Pliocene, while *Pecten vasseli* and *Ostrea tridacnaeformis* range throughout the Pliocene. The age of the basal beds of the Erythraean Series would therefore not be earlier than Middle Pliocene.

To turn now to the succession established by Dr. Macfadyen in the Farsan Islands. The earliest fossiliferous beds belong to the lower part of the Marly Limestone Series of his classification. They contain casts of *Apolymetis papyracea* [*Tellina lacunosa*] and *Diplodonta rotundata*, the presence of which at once suggests comparison with the cast beds of the lower part of the Erythraean Series of the Gulf of Suez region. These beds are succeeded (in places conformably) by the White Limestone with numerous well-preserved fossils, and cannot be very much older than this deposit. Leaving out of consideration a possibly extinct species of *Cardium*, preserved only as a cast, sixty-one molluscan species were collected by Dr. Macfadyen from this limestone, and all except three have proved to be undoubtedly identical with species now living in the Indo-Pacific province. The Reef Limestone, which overlies the White Limestone, has yielded, as it happens, a slightly larger proportion of extinct molluscan species, namely, five out of eighty-two. These figures are, however, sufficient to show that there can be no important difference in age between the Reef Limestone and the White Limestone, and it is clear that neither the latter deposit nor the underlying cast beds can be much older than Pleistocene.

I am not inclined to regard this result as having any bearing on the age of the basal cast beds of the Erythraean Series of the Gulf of Suez region. It is tempting to correlate the cast beds of the Marly Limestone Series with those of the so-called "Plio-Miocene" Series of the northern area, but, since all the easily recognized species found in these cast beds are forms now known to have a long geological range, it seems probable that they merely represent a peculiar facies-association likely to occur at any horizon. It is perhaps significant that *Pecten vasseli* and *Ostrea tridacnaeformis* were not found in the Farsan Islands. Their absence may, of course, merely be due to vagaries in distribution, but, since they are so abundant everywhere else in the region in beds which are here considered to fall within the Pliocene, a likely explanation of their absence is that they had already become extinct when the deposits of the Farsan Islands were laid down. As seen above, *Chlamys isthmica* and *Ch. lessepsii*, both of which occur in the Farsan Islands, seem to have originated at a later period than *P. vasseli* and *O. tridacnaeformis*, while *Ch. isthmica*, at least, persisted until late in Pleistocene times, as evidenced by its discovery by Drs. B. K. N. Wyllie and G. M. Lees in a low-level raised beach along the Sudan coast, with even the colour-ornamentation of the shell preserved (see Cox, 1929, p. 196).

Although, therefore, the collection now studied is of considerable interest as being the first of any importance to have been made from the late Cainozoic beds of so southerly a locality in the Erythraean area, I do not think that the recognition of the comparatively late age of all the beds collected from has any bearing upon the problem of the date of formation of the Red Sea.

II. LISTS OF SPECIES.

In the following lists an asterisk (*) indicates that the species is unknown living, an obelisk (†) that it has not been recorded living in the Erythraean region, although known to occur elsewhere in the Indo-Pacific province, and a double obelisk (‡) that it has not previously been recorded fossil in the Erythraean region.[1] The remaining species have been recorded both living and fossil. More familiar, but less correct, names for certain of the genera or species are printed in square brackets, subgeneric names in round brackets. Numerals in Clarendon type refer to the notes on certain of the species in the third section of the paper. The Roman capitals at the end of each line represent the localities of the species, as indicated at the top of the list of species from each horizon. All the specimens listed are deposited in the British Museum (Natural History).

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[1] For previous lists, see especially Newton, 1900, and papers cited in his bibliography, Bullen, 1901, Hall and Standen, 1907, and Newton, 1907.

I. **Mollusca from the basal cast beds of the Marly Limestone.**

The localities collected from were :—

A. Gebel Mukhezin, Seir Peninsula, Farsan Kebir.
B. Gebel Buttan, Seir Peninsula, Farsan Kebir.
C. Cliff facing Dumsuk Island, Seir Peninsula, Farsan Kebir.
D. Gebel Uzbah, Seir Peninsula, Farsan Kebir.

Gastropoda.

Bullus [*Bulla*] *ampulla* (Linné)	**B**

Lamellibranchia.

Anadara antiquata (Linné)	**C**
Lithophaga teres (R. A. Philippi) [**4**]	**B**
Cardita cf. *antiquata* (Linné) ‡	**B**
Codakia tigerina (Linné) [*exasperata* (Reeve)]	**B**
Diplodonta rotundata (Montagu) [**12**]	**B**
Apolymetis papyracea (Gmelin) [*Tellina lacunosa* Chemn.] [**13**]	**A, B, C**
Macrocallista cf. *florida* (Lamarck)	**A, C**
Dosinia pubescens (R. A. Philippi) ‡	**C**
Cardium (*Trachycardium*) cf. *leucostomum* Born	**B**
Lutraria intermedia (Deshayes MS., Reeve)	**B**
Gastrochaena sp.	**B**
Brechites [*Aspergillum*] cf. *vaginifer* (Lamarck) ‡	**D**

II. **Mollusca from the White Limestone forming the upper portion of the Marly Limestone.**

The localities collected from were :—

E. Dumsuk Island.
F. Zifaf Island.
G. Saso Island.

Gastropoda.

Fissurella (*Diodora*) *rüppellii* G. B. Sowerby	**F**
Clava [*Vertagus*] *recurva* (G. B. Sowerby)	**F**
Strombus (*Labiostrombus*) *fusiformis* G. B. Sowerby	**F**
Strombus (*Canarium*) *plicatus* Lamarck [*urceus* auct.]	**F**
Strombus (*Canarium*) *gibberulus* Linné	**F**
Strombus (*Canarium*) *fasciatus* Born	**F**
Natica marochiensis (Gmelin)	**F**
Polinices (*Naticina*) *powisiana* (Récluz) ‡	**F**
Erronea [*Cypraea*] *caurica* (Linné)	**F**
Erosaria [*Cypraea*] *ocellata* (Linné)	**F**
Pustularia [*Epona*] *cicercula* (Linné) ‡	**G**
Architectonica [*Solarium*] *perspectiva* (Linné)	**F**
Cymatium [*Triton*] (*Ranularia*) *vespaceum* (Lamarck) ‡	**F**
Cymatium [*Triton*] (*Ranularia*) *trilineatum* (Reeve)	**G**
Fusinus [*Fusus*] *tuberculatus* (Lamarck)	**F**
Nassarius [*Nassa*] (*Niotha*) *gemmulatus* (Lamarck)	**F**
Nassarius [*Nassa*] (*Niotha*) *albescens* (Dunker)	**F**
Turris [*Pleurotoma*] *garnonsii* (Reeve)	**F**

Conus arenatus, Hwass	F
Conus (*Dendroconus*) *erythraeensis* Beck	F
Terebra dimidiata (Linné) † ‡	F
Terebra babylonia Lamarck	F
Terebra andamanica Melvill and Sykes † ‡	F
Ancilla (*Sparella*) *acuminata* (G. B. Sowerby)	F
Atys naucum (Linné)	F
Atys (*Alicula*) *cylindrica* (Helbling)	F

Scaphopoda.

Dentalium aratorum Cooke [**3**]	F

Lamellibranchia

Navicula [*Arca*] *ventricosa* [Lamarck) ‡	F
Barbatia lacerata (Bruguière) ‡	F
Barbatia (*Acar*) *divaricata* (G. B. Sowerby)	F
Cucullaea concamera (Bruguière)	F
Glycymeris [*Pectunculus*] *arabica* (H. Adams)	F
Chlamys squamosa (Gmelin)	G
Chlamys senatoria (Gmelin)	E, G
Chlamys squamata (Gmelin) † ‡ [**5**]	G
Chlamys (*Aequipecten*) *sanguinolenta* (Gmelin)	E, G
Chlamys (*Aequipecten*) *lessepsii* (Fuchs)* [**7**]	G
Chlamys (*Aequpecten*) *isthmica* (Fuchs)* [**8**]	E
Spondylus maris-rubri Bolten [*aculeatus* Chemn.]	E, F, G
Plicatula menkeana Finlay [*imbricata* Menke]	G
Lima lima (Linné) [*squamosa* Lamarck]	G
Ostrea cucullata Born	G
Ostrea crista-galli (Linné)	E, F, G
Ostrea crenulifera G. B. Sowerby	F
Lucina dentifera Jonas ‡	F
Codakia tigerina (Linné) [*exasperata* (Reeve)]	G
Divaricella macandreae (H. Adams)	F
Thyasira [*Cryptodon*] *tumida* (Reeve) [*globosa* auct.] [**11**]	G
Diplodonta rotundata (Montagu) [**12**]	F
Macrocallista florida (Lamarck)	F
Pitar [*Cytherea*] *hebraeus* (Lamarck) ‡	F
Lioconcha ornata (Dillwyn) [*picta* (Lamarck)]	F
Circe corrugata (Dillwyn)	F
Dosinia histrio (Gmelin) ‡	F
Clementia papyracea (Gray)	E, F
Cardium (*Acanthocardia*) sp. † ‡ [**15**]	E
Cardium (*Trachycardium*) *leucostomum* Born	E, F
Cardium (*Fragum*) *fornicatum* G. B. Sowerby	F
Tridacna croacea Lamarck	F
Corbula sulculosa H. Adams	F
Corbula taitensis Lamarck	F

III. **Mollusca from the Reef Limestone.**

The localities collected from were :—

H. Zifaf Island.
I. Kamaran Island.
J. Abulad Island.
K. El Gabr, Farsan Kebir.
L. Near Mharak Village, Farsan Kebir (cast bed below Reef Limestone).
M. Seluba Island.
N. Dumsuk Island.
O. Gizan Peninsula.

Gastropoda.

Trochus maculatus Linné	?
Trochus (*Tectus*) *dentatus* Forskål	?
Gibbula (*Forskalena*) *declivis* (Forskål)	I
Nerita forskaelii Récluz [*crassilabrum* Smith]	N
" *Cerithium* " *spathuliferum* G. B. Sowerby ‡ [**1**]	H
" *Cerithium* " *erythraeonense* Lamarck	M
Clava [*Vertagus*] *fasciata* (Bruguière)	H, M
Strombus (*Labiostrombus*) *fusiformis* G. B. Sowerby	I
Strombus (*Canarium*) *plicatus* Lamarck [*urceus*, auct.]	I
Strombus (*Canarium*) *gibberulus* Linné	H, M, N
Strombus (*Canarium*) *fasciatus* Born	H
Tibia insulae-choräb Bolten [*Rostellaria curvirostris* Lamarck]	H, N
Terebellum terebellum (Linné) [*subulatum* Lamarck]	L
Polinices (*Naticina*) *mammilla* (Linné)	M, O
Lyncina [*Cypraea*] *carneola* (Linné)	N
Lyncina [*Cypraea*] *camelopardalis* (Perry)‡	H
Erronea [*Cypraea*] *caurica* (Linné)	M
Erosaria [*Cypraea*] *erosa* (Linné)	M
Architectonica [*Solarium*] *perspectiva* (Linné)	H
Tonna [*Dolium*] *costata* (Menke) † ‡	?
Ficus [*Pyrula*] *reticulatus* (Lamarck)	I
Fusinus [*Fusus*] *tuberculatus* (Lamarck)	H
Latirus polygonus (Gmelin)	M
Latirus turritus (Gmelin)	M
Volema [*Melongena*] *paradisiaca* Bolten	H
Nassarius [*Nassa*] *arcularia* (Linné), var. *pulla* (Linné)	I
Nassarius [*Nassa*] (*Niotha*) *albescens* (Dunker)	I
Mitra versicolor Martyn ‡	H
Vexillum [*Turricula*] (*Uromitra*) *macfadyeni* Cox * [**2**]	I
Vexillum [*Turricula*] (*Pusia*) *glandiforme* (Reeve) ‡	I
Murex tribulus Linné	H
Turris [*Pleurotoma*] *garnonsii* (Reeve)	I
Conus arenatus Hwass	H, M, N
Conus (*Lithoconus*) *eburneus* Hwass †	H
Conus (*Rhizoconus*) *sumatrensis* Hwass ‡	H
Conus (*Cylinder*) *aulicus* Linné ‡	H
Conus (*Cylinder*) *pennaceus* Born ‡	H
Conus (*Hermes*) *nussatella* Linné	M
Terebra andamanica Melvill and Sykes † ‡	H
Oliva miniacea (Bolten) [*erythrostoma* Lamarck] †	H, M
Oliva (*Carmione*) *bulbosa* (Bolten) [*inflata* Lamarck]	O
Bullus [*Bulla*] *ampulla* (Linné)	H, L

Scaphopoda

Dentalium aratorum Cooke [**3**]	I

Lamellibranchia.

Navicula [*Arca*] *ventricosa* (Lamarck) ‡	H
Anadara antiquata (Linné)	H, I
Barbatia fusca (Bruguière)	H, I
Barbatia lacerata (Bruguière) ‡	H
Glycymeris [*Pectunculus*] *livida* (Reeve) ‡	H
Glycymeris [*Pectunculus*] *arabica* (H. Adams)	N
Glycymeris [*Pectunculus*] *pectunculus* (Linné)	I
Limopsis multistriata (Forskål)	I
Chlamys senatoria (Gmelin)	I, K
Chlamys (*Aequipecten*) *sanguinolenta* (Gmelin)	H, I, J
Chlamys (*Aequipecten*) cf. *scabrellus* (Lamarck) * [**6**]	K
Chlamys (*Aequipecten*) *~~less~~epsii* (Fuchs) * [**7**]	K, N (?)
Chlamys (*Aequipecten*) *farsanensis* Cox * [**9**]	I

Chlamys (*Decadopecten*) *plica* (Linné)	I, K
Plicatula menkeana Finlay [*imbricata* Menke]	H, I, K
Lima lima (Linné) [*squamosa* Lamarck]	H, L
Ostrea gryphoides (Schlotheim) †	L
Ostrea crista-galli (Linné)	H
Ostrea turbinata Lamarck	H, O
Cardita canaliculata Reeve † ‡ [**10**]	I
Crassatellites [*Crassatella*] *radiatus* (Lamarck) ‡	I
Codakia tigerina (Linné) [*exasperata* (Reeve)]	H, I, L, N
Divaricella macandreae (H. Adams)	I
Diplodonta rotundata (Montagu) [**12**]	O
Tellina sulcata Wood	O
Apolymetis papyracea (Gmelin) [*Tellina lacunosa* Chemn.] [**13**]	O
Macrocallista florida (Lamarck)	O
Lioconcha ornata (Dillwyn) [*picta* (Lamarck)]	H
Gafrarium [*Circe*] *pectinatum* (Linné)	O
Dosinia histrio (Gmelin) ‡	I
Antigona lamellaris Schumacher ‡	I
Antigona reticulata (Linné)	H
Antigona (*Ventricola*) *orientalis* Cox * [**14**]	H, J
Clausinella foliacea (R. A. Philippi) ‡	I
Cardium (*Trachycardium*) *leucostomum* Born	H, N
Tridacna croacea Lamarck	M
Chama lazarus Linné	H
Chama brassica Reeve ‡	H
Corbula taitensis Lamarck	I

IV. **Mollusca from a 20 ft. Raised Beach.**

Locality : Ras Hassis, Farsan Kebir.

Gastropoda.

Tibia insulae-choräb Bolten [*Rostellaria curvirostris* Lamarck].
Murex (*Chicoreus*) *virgineus* (Bolten) [*anguliferus* Lamarck].

Lamellibranchia.

Navicula [*Arca*] *ventricosa* (Lamarck). ‡
Andara antiquata (Linné).
Chlamys squamosa (Gmelin).
Lima lima (Linné) [*squamosa* Lamarck].
Chama lazarus Linné.
Chama limbula Lamarck [**16**].

III. NOTES ON CERTAIN OF THE SPECIES.

[**1**.] "*Cerithium*" *spathuliferum* G. B. Sowerby (1855, *Thes. Conch.*, ii, p. 859, pl. clxxx, f. 94).

An easily recognized but apparently very rare form. The sutures are obscured by a row of projecting, compressed, spatula-like tubercles, situated on the anterior part of each whorl. Two further rows of similar tubercles are developed on the last whorl, one above the sutural row and one below. As Cooke and Tryon have suggested, this may be a variety of *C. munitum* G. B. Sowerby, although the development of the ornamentation follows quite a different course in the two forms and it is not until the last whorl that the sculpture becomes similar. The type-locality of *C. spathuliferum* is unknown. M'Andrew recorded a specimen from Suez, but, according to Cooke, this was merely an abnormal *C. rüppelli* Phil. Von Martens has recorded the species (with a query) from Mauritius.

[**2**.] *Vexillum* (*Uromitra*) *macfadyeni* Cox (1930, *Proc. Malac. Soc.*, xix, p. 77, pl, viii *a*).

A species with the same type of reticulate sculpture as *V. obeliscus* (Reeve), the axial riblets being slightly stronger than the spirals. It differs from Reeve's species in being more slender and slightly larger, in having an obscure shoulder to its whorls, and in the more pronounced curve of the anterior canal of its aperture.

[**3**.] *Dentalium aratorum* Cooke (1885, *Ann. Mag. Nat. Hist.* [**5**], xvi, p. 273).

Three supposedly distinct species, *D. aratorum*, *D. lineolatum*, and *D. clavus*, were described in Cooke's paper on the Gulf of Suez fauna, but were not figured. Cooke's type-specimens have since been figured by Boissevain (1906, *Siboga-Exp. Monogr.* liv, p. 25, pl. v, f. 25–34), who unites them as one species, which she names *D. macandrewi*. Since the introduction of a fourth name was unnecessary, I adopt the name *D. aratorum* for the species, this being the first in Cooke's list. It is possible that the *D. reevei*, Deshayes MS., recorded from the same region by Fischer (1871, *Journ. de Conch.*, xix, p. 212), may have been the same form; Fischer's description, however, is too inadequate for its identity to be established.

The Farsan specimens referred to this species are up to 60 mm. in length, slender, gently curved, and sculptured with 9–12 rounded ribs, separated by interspaces of at least twice their own width; about three secondary riblets are visible in each interspace. The variation in the number of ribs is illustrated by the fact that, of twenty-one specimens examined, two have 9 ribs, six have 10, eleven have 11, and two have 12. These specimens, on the average, are larger than Cooke's types, and their primary ribs are not bisected longitudinally. I have, however, no doubt that they belong to the same species. This is the species from the raised beaches of Sinai which Newton (1900, p. 546) recorded as *D. octogonum* Lamarck (= *octangulatum* Donovan). In the true *D. octangulatum*, which occurs in the Indian Ocean, the number of ribs is smaller (usually eight) and less variable.

[**4**.] *Lithophaga teres* (R. A. Philippi).

A species of *Lithophaga* is one of the most abundant fossils in the cast beds at the base of the Marly Limestone. It is undoubtedly the form which occurs in a similar state of preservation in the "Plio-Miocene" of the Gulf of Suez region and was recorded by Newton (1900, p. 548) as *L. avitensis* (Mayer-Eymar). *L. avitensis* was originally described from the Miocene of the Vienna Basin (Hoernes, 1867, *Abh. Geol. Reichsanst. Wien*, iv, p. 354, pl. xlv, f. 12*a*–*c*), but, according to Dollfus and Dautzenberg (1920, *Mém.*

Soc. Géol. France (Pal.), 27, p. 390), it is quite inseparable from the living Mediterranean species, *L. lithophaga* (Linné). Shopland (1902, *Proc. Malac. Soc.*, v. p. 178) has recorded *L. lithophaga* from Aden, while Lamy (1919, *Bul. Mus. Hist. Nat. Paris*, xxv, p. 253) has described a Red Sea species, *L. robusta,* which is said to be very close to the Mediterranean species. After careful comparison with recent shells, however, I am convinced that the fossil casts belong, not to *L. lithophaga*, but to the common Indo-Pacific species, *L. teres* (Philippi). They agree perfectly with this species in shape, while the length does not exceed 60 mm. in any of the specimens examined and corresponds to the normal length of *L. teres.* Young specimens of *L. lithophaga* differ very little from *L. teres* in shape, but full-grown specimens are much larger. Recent specimens of the two species, of course, may be distinguished by the colour and sculpture of the shell.

[**5**.] *Chlamys squamata* (Gmelin).

The specimen recorded has been described and figured in my paper on the post-Miocene Ostreidae and Pectinidae of the Red Sea region (1929, p. 190, pl. xi, f. 3). The species does not seem to have been found living in the Erythraean region or anywhere on the western side of the Indian Ocean.

[**6**.] *Chlamys* (*Aequipecten*) cf. *scabrellus* (Lamarck).

This specimen has also been described and figured in my previous paper (1929, p. 192, pl. xii, f. 1*a*, *b*). Its occurrence in the Red Sea deposits is very interesting, since *Ch. scabrellus* is a well-known Mediterranean Neogene species, now extinct. Vredenburg, however, has recorded it from the Indian Miocene.

[**7**.] *Chlamys* (*Aequipecten*) *lessepsii* (Fuchs).

This rather variable species has also been dealt with by me in my previous paper (1929, p. 192, pl. xi, f. 1*a*, *b* and pl. xii, f. 2). It has usually been recorded as *Pecten fischeri* Vassel in Egyptian Geological Survey publications. Apparently it ranges from the Middle or Upper Pliocene to the Pleistocene. Stefanini has recorded it from S.E. Arabia and Douglas from Persia, but it has not yet been found in East Africa.

[**8**.] *Chlamys* (*Aequipecten*) *isthmica* (Fuchs).

Another extinct species dealt with in my previous paper (1929, p. 195, pl. xii, f. 4). By some authorities it has been regarded as a variety of *Ch. lessepsii,* and it certainly seems to have about the same range. I have preferred to distinguish the two forms.

[**9**.] *Chlamys* (*Aequipecten*) *farsanensis* Cox (1929, p. 196, pl. xiii, f. 2).

This species, known only by the holotype, belongs to the same group as the two last-mentioned forms. The ornamentation consists of nine very prominent ribs, which are separated by much wider interspaces.

[**10.**] *Cardita canaliculata* Reeve (1843, *Conch. Icon.* i, *Cardita* sp. 40).

The specimen recorded is immature, but agrees very well with young specimens of *C. canaliculata*, with which *C. cardioides* Reeve (loc. cit. *Cardita* sp. 49) is synonymous. Neither form has been recorded from the Red Sea, but Smith (1891, *Proc. Zool. Soc.*, p. 429) considers *C. cumingii* Deshayes, which is an Erythraean form, to be another synonym. This, however, differs in shape and size to so great an extent that it is to be doubted if Smith's view is correct.

[**11.**] *Thyasira tumida* (Reeve).

This rotund, gibbose species is very abundant in the Red Sea deposits, and has usually been recorded as *Lucina* [*Loripes, Cryptodon*] *globosa* (Forskål). Lynge, however, has examined Forskål's type-specimen and has stated (1909, *Kgl. Danske Vidensk. Selsk. Skr.* [**7**], v, p. 175) that his species has been wrongly interpreted by authors, the type-specimen being a *Diplodonta*. As explained in my recent paper on East African Neogene mollusca (1930, p. 128), Reeve's trivial name *tumida* is therefore best adopted for the *globosa* of authors.

[**12.**] *Diplodonta rotundata* (Montagu).

There can be no doubt that this well-known European species is also to be found in the western part of the Indian Ocean at the present day. Several authors have recorded it from the Red Sea and Aden, and Melvill and Standen from the Persian Gulf. Besides numerous examples from the Red Sea deposits, agreeing perfectly with Mediterranean specimens, I have also seen specimens from the Pleistocene of East Africa (Cox, 1930, p. 156). The very gibbose form, *D. savignyi* Vaillant, which should be known as *D. globosa* (Forskål), is undoubtedly specifically distinct from *D. rotundata*, although Fourtau (in Hume, 1916, p. 93, pl. vii) regards it as a " mutation " of that species.

[**13.**] *Apolymetis papyracea* (Gmelin).

Figured as *Tellina lacunosa* Chemn. by Hume (1916, pl. via). Gmelin's trivial name should replace that of Chemnitz, who was not a binomial author, while the species is now placed in the genus *Apolymetis* Salisbury (1929, *Proc. Malac. Soc.*, xviii, p. 258), recently substituted for *Metis* H. and A. Adams, on account of its pre-occupation. In Miocene times this was a very abundant species in the Mediterranean region. At the present day it is found off the west coast of Africa, but not in the Mediterranean ; while a form which to me is indistinguishable from it is distributed sparsely through the Indo-Pacific province (Aden, Siam, China). The Red Sea fossil casts agree perfectly with Recent specimens from Aden. Lynge (1909, *Kgl. Danske Vidensk. Selsk. Skr.* [**7**], v, p. 205) and Lamy (1918, *Bul. Mus. Hist. Nat. Paris,* xxiv, p. 168) prefer to regard this Indo-Pacific form as a distinct species, for which they adopt R. A. Philippi's trivial name, *coarctata*. Geographical distribution alone, however, is an unsatisfactory criterion for specific discrimination. In the present collection this species occurs among the fossils from the Reef Limestone as well as from the Marly Limestone at the base of the series. It must be emphasized that it cannot be considered as an index-fossil of the Miocene in the Erythraean region.

[**14**.] *Antigona* (*Ventricola*) *orientalis* Cox (1930, p. 129, pl. xv, f. 2*a–c*, 3).

This species is most closely related to the West Indian form *A.* (*V.*) *rigida* (Dillwyn), but is smaller and differs in other particulars. In East Africa it occurs both in Pliocene and Pleistocene deposits. It is unknown living, although it must be mentioned that Issel recorded *A.* (*V.*) *rigida* from the Gulf of Akaba, and it is difficult to suggest any known living Indo-Pacific species to which this record might refer. *A.* (*V.*) *toreuma* (Gould) is somewhat similar to the species now recorded, but differs in the crenulaton of its concentric frills as well as in its narrower lunule and slightly different dentition.

[**15**.] *Cardium* (*Acanthocardia*) sp.

This specimen is a cast, comparable in shape to the living Indian Ocean species *C. asiaticum* Bruguière, but with only 22-23 ribs—fewer than are normally found in that species. It may, however, represent an extreme variety of *C. asiaticum*. A very similar cast was collected by Mr. R. H. Mitchell from the "Plio-Miocene" of Towila Island.

[**16**.] *Chama limbula* Lamarck.

See Lamy, 1917, *Bul. Mus. Hist. Nat. Paris*, xxiii, p. 206 and 1921, ib., xxvii, p. 308, and Cox, 1930, p. 161 for a discussion of this species. Among other forms I include in its synonymy *Ch. corbierei* Jonas, *Ch. nivalis* Reeve, *Ch. cornucopia* Reeve, and *Ch. rüppellii* Reeve, all recorded from the Red Sea.

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U-Shaped Burrows in the Lower Lias of Somerset and Dorset.

By A. W. COYSH, M.Sc., F.G.S.

THE weathered surfaces of the limestones and calcareous shales of the Lower Lias in Somerset and Dorset sometimes exhibit curious paired markings. On careful examination these prove to be cross sections of U-shaped burrows of organic origin, appearing as two circular markings connected by a shallow depression or by a slight variation in the character of the matrix. Similar burrows have been described from the Lower Estuarine sandstone of Blea Wyke, on the Yorkshire coast.[1] Dr. F. A. Bather has discussed their origin and structure in detail and has assigned them to the genus *Arenicolites*,[2] which was established by J. W. Salter for "all worm burrows with double openings".[3] Other species of the genus have been described from arenaceous and argillaceous beds of Longmyndian, Ordovician, and Upper Carboniferous age, but as far as the author is aware, the species here recorded is the first that has been mentioned from the calcareous rocks of the Lower Lias of England.

The average diameter of the Liassic burrows varies from 4 to 7 mm., while the connecting depression does not exceed 2·5 cm. Vertical sections reveal a laminated rock which suggests deposition in tranquil water. The laminae are festooned between the limbs of the U, owing to the collapse of the lower portion of the tube when the worm decayed.

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[1] J. W. Stather, *Proc. Yorks. Geol. Soc.*, New Series, xx, 1925, pt. ii, 182–4.

[2] Ibid., 184–99.

[3] *Q.J.G.S.*, xiii, 1857, 204.

The limestone in which the figured specimen occurs yielded 8·1 per cent of insoluble matter when treated with dilute HCl. The material filling the burrows is lighter in colour and consists of fine grained calcareous " mud " containing 19·8 per cent of insoluble matter. The fact that the matrix and infilling material differ in composition, suggests that the walls of the tube may have been strengthened with mucus. In the figured specimen it would appear that the wall became detached at C from the side of the burrow, allowing material of slightly different composition to enter. The laminae in the vicinity of this portion of the tube are slightly disturbed.

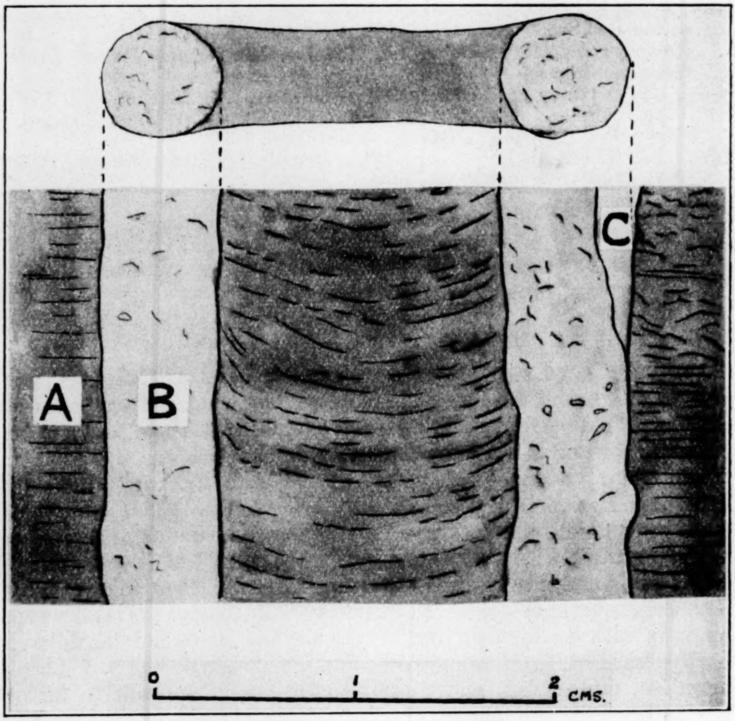

Fig. 1.—(Above) Horizontal section of *Arenicolites lymensis* sp. nov. from the Lower Lias of Lyme Regis. (Below) Vertical section of the same specimen. A. Laminated dark grey argillaceous limestone (insoluble residue 8·1 per cent). B. Homogeneous infilling of burrow, a light grey calcareous " mud ". (Insoluble residue 19·8 per cent). C. Lighter grey calcareous " mud ".

The burrows were probably filled partly by mud that had passed through the alimentary canal of the worm, partly by mud settling from the water above. They must have been filled before the sinking of the bottom of the U-tube due to the decay of the dead organism, or lateral pressure would have caused the sides of the U to collapse.

Specimens vary greatly in size according to the lithology of the rock in which they occur. The average width of the U is from 2·5 to 3 cm., but specimens from the tabular limestones (Insol. res. 13·1 per cent) of the *planorbis* horizon at St. Audries', West Somerset, are much smaller, ranging up to 1·3 cm. in width. Salter recorded both large and small varieties of *Arenicolites didymus* from the Longmyndian. This variation in size may be accounted for by variation in depth and food supply. The modern lug-worm, *Arenicola marina*, attains a greater size in the laminarian zone than in the littoral zone, flourishing in a mud containing decomposing organic matter.[1]

Arenicolites lymensis sp. nov.

Diagnosis.—U-shaped burrows, probably formed by a Polychaet worm, in shallow water. Tube diameter varying from 4 to 7 mm., and width of the U from 1 to 3·5 cm. Depth of burrow about 10 cm.

Holotype.—Specimen from the Lower Lias of Lyme Regis. (Brit. Mus. Coll. A. 4400.) Other localities include :—

(*a*) St. Audries', West Somerset, in the tabular limestones of the *planorbis* horizon, immediately east of Esson's Gully, where the Hettangian deposits are faulted against the Keuper marls. (B. M. Coll. A. 4403.)

(*b*) Kilve Pill, West Somerset, in the *bucklandi* zone (sensu lato). (B. M. Coll. A. 4406.)

(*c*) Keeling's Quarry, Keynsham, in the calcareous shales of the Hettangian deposits below the *calcicosta* limestone.[2]

(*d*) Bowldish Quarry, near Radstock, from the limestone at the top of the *bucklandi* bed (above the *gmuendense* horizon). (B. M. Coll. A. 4404–5.)

Further Notes on Structural Types and Earth Movements.

By J. S. LEE.

IN a previous paper[3] published in the GEOLOGICAL MAGAZINE, the writer made an attempt to discuss the mechanism of earth movement on a continental scale purely from a tectonic point of view. The problem is so vast and involved that some of the vital points were hardly touched upon, partly because of lack of space and partly of literature. The arrival of the admirable works of Dr. A. du Toit [1] and Dr. E. Krenkel [2] has enabled the writer to deduce the mechanism of the movements of South Africa directly from its tectonic features, which process is thought to be far more reliable than the type of argument used in the previous case although the results arrived at are essentially the same. The earlier movements in North America are now seen to furnish evidence of the same type of mechanism as that which staged the later movements. An epsilon type of structure has been recognized in Eastern China, which was then described as a mere arc. The problem of the distribution of concealed coalfields in England was in the previous paper barely touched upon. It is now proposed to consider some of the critical points bearing on the problem.

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[1] See Ashworth, *Liverpool Marine Biological Committee*, 1904, 2–5 and 29.

[2] J. W. Tutcher, *Proc. Bris. Nat. Soc.*, IV, V, 1923 (for 1922), 271–2.

[3] J. S. Lee, "Some Characteristic Structural Types in Eastern Asia, etc," GEOLOGICAL MAGAZINE, LXVI, Nos. 782–5, 1929.

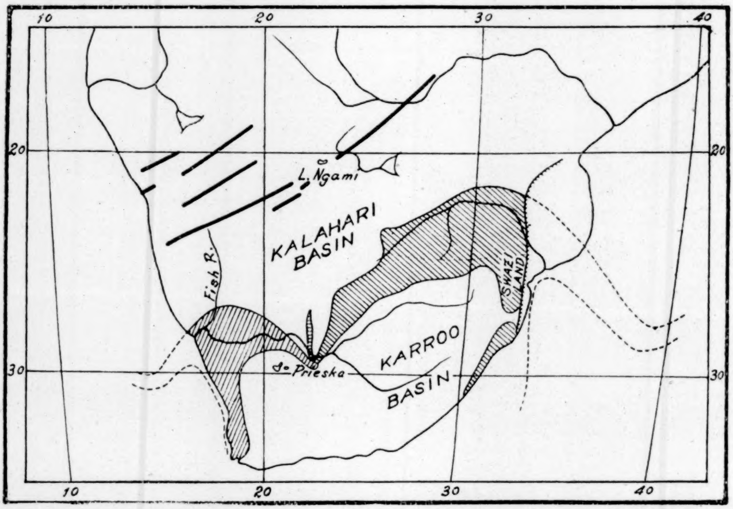

FIG. 1.—Structural types in South Africa. Thick lines = trend of ancient massifs forming the xi structure; shaded areas = uplifted masses forming the epsilon structure. Broken lines suggest the probable extension of shattered and subsided parts of the epsilons; the structure of the eastern epsilon (hatched to the right) being rendered highly complicated by the presence of the Bushveld Igneous Complex, which probably owes its origin to the E.–W. zonal deformation. (Adapted from A. L. du Toit and E. Krenkel.)

(1) *Structural Types and Movements of South Africa.*—In South Africa two epsilons are developed side by side. Parts of these epsilons are now broken down. Nevertheless, the essential features

[1] *Geology of South Africa*, Oliver and Boyd, Edinburgh, 1926.

[2] *Geologie Afrikas* (*Geologie der Erde*), Zweiter Teil, Borntraeger, Berlin, 1928.

are still recognizable. The eastern epsilon is developed on a much grander scale than the western one. The former covers the eastern part of the Cape Province, Griqualand West, Orange Free State, Natal, Swaziland, Transvaal, the southern part of Portuguese East Africa, and probably extends into Southern Rhodesia. The axis of this system traverses Swaziland, Zululand in a north-south direction. Then it is obliquely cut off by the coast of the Indian Ocean. The fact, however, that it extends still further south is clearly shown by strips of outcrops of the Old Granite and Gneiss, Rhodesian Schists and the Table Mountain Series stretching as far south as Pondoland. Throughout this distance of several hundreds of miles, the basal rocks, though irregularly exposed, are generally folded to a marked degree, and in places overthrust from the east.

The western wing of this epsilon forms the boundary between the Kalahari Basin on the north-west and the Karroo Basin on the south-east. All along this swell of ancient rocks which cover the south western Transvaal, northern Orange Free State, and Griqualand West, the Transvaal, and the Ventersdorp Systems together with stretches of the Witwatersrand Series, belts of the Black Reef, and huge masses of the Campbell Rand Dolomite are forced up in a N.E.-S.W. trend.

The eastern wing is not seen. But there cannot be much doubt that it does exist in the southern part of Portuguese East Africa under the cover of the younger deposits. Further south-east its fragmentary remains must be found in the Indian Ocean.

The western epsilon occupies the western part of the Cape Province, Bushman Land, Gordonia, and the lower reach of the Great Fish River. The eastern wing of the system commences at the Doornberg on the upper reach of the Orange River with highly folded strata of the "Primitive" and Nama rocks striking N.W. From Upington westward, these rocks sweep round almost due west past the Kharas Mountains, then enter the valley of the Great Fish River, where they generally strike N.E. In the last-named region we see a part of the western wing of the system. Further south-west it must have been faulted down into the Atlantic. The apex of this system is probably located somewhere east of the Great Kharas Mountain and north of Kalkfontein. From Cape Town northward there is an extensive stretch of compressed folds which represent the axis of the system. The Diamond Mountains are distinctly an alien feature whose origin is probably to be traced to the breaking down of the south-western extension of South-West Africa.

These two epsilons meet at the longitude of Prieska, where two structural types are superimposed. The one is a reflex epsilon attached to the main epsilons already discussed; and the other is a geniculate type due to the juxtaposition of the two epsilons; for, if the region referred to is covered by a simple reflex epsilon, the rocks in the Doornberg would not show an abrupt contact with those that form the north-western wing, and if the region is covered by a pure geniculate type of structure the axial zone of the Langeberg and Korannaberg would not have been developed.

Apart from these structural types we have another instructive type developed in South-West Africa, occupying a vast territory. This is the xi structure which is revealed in the Komas Highlands, the Omatako Lowlands, the southern part of the Otavi Highland, and the strips of ancient masses that betray the tectonic traits of the sub-surface of the Kalahari Basin between Gobabis and the south of the Lake Ngami. The rocks in these regions are generally impressed with a N.E. strike ; and in the case of the Gobabis-Ngami zone there are probably some more or less extensive thrusts of that trend.

All these tectonic types had been completed, at least in their outlines, before the lowest Karroo beds were laid down. Later movements probably served to enhance, and only to a small extent modify, their characteristic features.

A considerable light is shed by these tectonic types upon the movements of South Africa. The presence of the eastern epsilon not only shows that South Africa sheared northward to the greatest extent in the longitude of the Swaziland axis but demonstrates with force that a part of the South African continent must have sunk into the Indian Ocean ; for, neither in Madagascar nor in India do we find to-day any structural elements that could make up the lost wing and axis of this epsilon system.

Further, we are enabled to see why the Great Rift Valleys are developed in the positions where they are. With the Eurasian epsilon pressing from the north and the eastern epsilon of South Africa from the south, the region lying in between would be rammed, as it were, by the driving mass with its more or less acute front, and would be therefore pressed asunder when the driving force was strong enough to overcome its tensile strength or cohesion and to dislodge the adjoining masses.

The xi structure of South West Africa argues, too, for a northward shearing movement of South Africa as a whole against some stumbling block on the west. That stumbling block could not be a continental mass, but would more likely be an ocean floor which, as we have already seen, always behaves as a resisting mass against shearing movements of the continental sheets. Thus it becomes probable that there was an ocean of some size, probably the southern extension of the Poseidon of Professor Schuchert, that had already existed in early geological times.

(2) *The Movements of North America.*—In the previous paper the writer endeavoured to discuss the dominant structural types in North America and their causal movements. Emphasis was laid on the chronological difference of the orogenic phase in the Appalachian and the Cordilleran Ranges. While it is considered to be true that the uplifting of the Cordilleras was largely due to a clockwise torsional movement of the whole continent during the

Laramide revolution, the same argument may be applied to the formation of the Appalachian mountains during the Caledonian and Hercynian revolutions. During these early movements the North American Continent was probably connected, in its north-eastern corner, with Greenland, and possibly had some continental connection with north-western Europe. With such a large land-mass as Greenland stretching high into the north, the balance of the horizontal component of the rotational force would naturally favour a counter-clockwise rotation of North America. Hence would result an intensified movement in the eastern wing of the North American epsilon—the Appalachian zone—and a corresponding alleviation of pressure in the western wing of the same system—the Palaeo-Cordillera. The Caledonian Chain which extended across the then narrower northern Atlantic appears to have been brought about through this very process. With the breaking away of Greenland from North America, the twisting movement of the continent reversed its direction.

With regard to zonal disturbance in North America, the Ouachita Mountains in Arkansas and Oklahoma were mentioned as an example. Now recent research [1] has shown that there is another thrust zone of east-west trend disclosed in the Boston Basin. So powerful is this structural zone that even the mighty Appalachian Mountains deviate from their normal course on their approach to this zone. The circumstances are similar to those that are observed in the indentations of the Eastern Asiatic island chains on their meeting with east-west zones coming from the main land. It is of interest to note that the axis of the Boston Basin approximately agrees with the Inshan zone in Asia and Pyrenees zone in Europe, and is separated from the Ouachita Mountains by about 8° of latitude.

(3) *Epsilon of Eastern China.*—Recent exploration in Eastern China has demonstrated that the eastern part of the Tsinling Range is not bent into a simple arc as was first supposed, but forms an epsilon of moderate size. This epsilon covers the whole area of northern Anhuei, eastern Hupeh, northern Kiangsi and southern Kiangsu (see Fig. 2). It excels in beauty because of the graphic development of two reflex epsilons, one on each side of its wings. The axis of the main epsilon conforms with the Hoshan Arc which is composed of old gneisses and schists with flanking Palaeozoics, and follows the course of the lower Yangtze below the mouth of the Tungting Lake. The innermost or northernmost arc is located along the middle course of the Hwai River and to the south of it. Here the inverted Ordovician and Carboniferous strata are thrust from the south-east and south-west upon a low-lying mass which is covered by alluvium. Further north, hill ranges rise above a flat plain running from west of south to east of north, and pointing to

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[1] M. Billings, "Structural Geology of Eastern Part of Boston Basin," *Amer. Journ. Science*, xviii, 1929, 97–107.

the centre of the arc just referred to. These ranges make their first appearance to the west of a small station named Fulichih on the Tientsin-Pukow Railway, and extend to the north of Hsuchoufu. Then folds of east-west trend suddenly appear disclosing traces of the true Tsinling folding.

The eastern reflex epsilon is developed in the hill ranges between Nanking and Chinkiang; and the western one covers the south-eastern part of the Province of Hupeh and the north-western part of the Province Kiangsi where the reflex arcs agree, though not exactly, with the course of the Yangtze.

The existence of this epsilon indicates that Eastern China, or to be more exact, the northern part of the Provinces of Anhuei and Kiangsu, has sheared more or less as an independent block not exactly southward but slightly to the west of south—a conclusion which entirely harmonizes with those already reached from the configuration of the other structural types developed in the neighbouring areas.

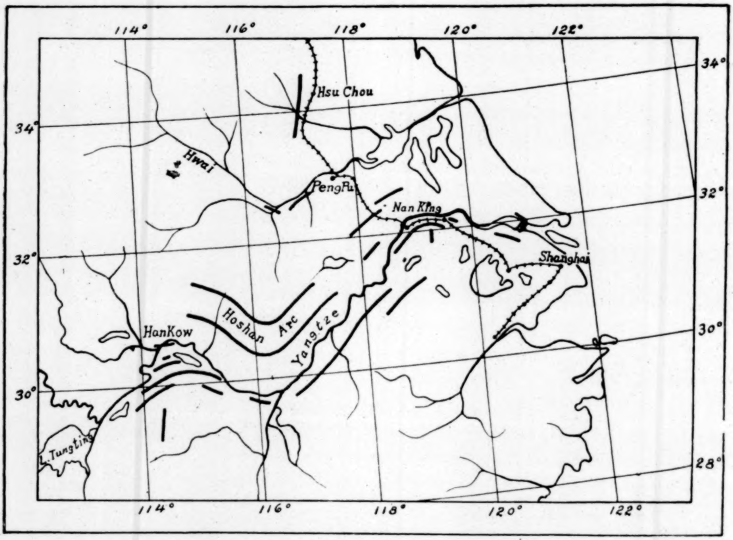

Fig. 2.—Plan of the structural elements forming the epsilon of Eastern China.

(4) *The Concealed Coalfield in England.*—Having realized the tectonic integrity and importance of the epsilon structure in determining the tectonic plan of so many areas on the globe, it would seem apropos to set forth a few suggestions as to the limitation of the buried coalfields in England. It must be said, however, that the writer's ignorance of some of the critical data either published or unpublished obtained in borings or otherwise, and of the views

held by most of the British geologists who have dealt with the problem, does not justify any attempt to claim a place in the detailed discussions on the subject. The chief interest is here focussed on the suggestive *exposé* which appeared in this Magazine by Professor A. H. Cox and Dr. A. E. Trueman,[1] and more especially by Dr. R. H. Rastall.[2]

Dr. Rastall has rightly laid the emphasis, as do Cox and Trueman, on the Cimmerian phase of movement as a factor contributing to the elucidation of the earlier structures of the English Midlands. The argument naturally lends strong support to the general theory that renewed movements in a region often follow old-established lines. It might be fittingly mentioned here that the writer has attempted to show elsewhere why this should be the case under prevailing circumstances.

In dealing with the underground structure of the Midlands and the eastern part of England this principle is particularly important; for, otherwise the post-Permian structural lines cannot be considered to afford any guidance in the search for the older axes which had determined the distribution of the coal-basins. Dr. Rastall has paved a long way by piecing together the scattered facts for research along these lines.

The following suggestions are, however, offered from an entirely different point of view, so as to see how far the results thus arrived at would differ from, or agree with, those already obtained by Dr. Rastall.

It is thought at the outset that in England, as often elsewhere, two important orographic elements were brought to prominence by the Hercynian movement. The one has an east-west axis continued into the continent, and the other is an epsilon of which only parts are now disclosed at the surface. These two elements undoubtedly influence each other in some way, but they are of different origin, and would each, therefore, play a rôle of its own.

Of the east-west axis evidence has been accumulating. It is seen in the strong disturbances of the Pembroke and Radstock coalfields; and the same axis probably passes through Kent under the younger strata so as to connect itself with the coalfields of central Belgium. Dr. Rastall seems to be inclined to believe, as does Professor H. Louis, that "very flat lying dislocations" are the cause of the apparent repetition of coal seams in certain borings in Kent. Granting that this is the case, the facts would seem to meet our theoretical requirement.

On the flanks of this east-west zone of strong folding, one is likely to find Coal Measures of workable value; while in the zone itself the beds are probably much broken up or otherwise disturbed so that even if there are coal seams which escaped denudation their economic value would be relatively limited, especially when they are buried in depth. The Kent and Dover coalfield, together with the coalfield of Northern France in the south, are probably examples of coalfields determined by this line of disturbance. Their extension should therefore be sought in an approximately east and west direction.

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[1] "Intra-Jurassic Movements in the Midlands," Geol. Mag., LVII, 1920, 198–208.

[2] "On the Tectonics of the Southern Midlands," Geol. Mag., LXII, 1925, 193–222. "The Underground Structure of Eastern England." Geol. Mag., LXIV, 1927, 10–21.

As to the epsilon structure, a few words would not perhaps be wasted if we were to bring out the characteristic features of that tectonic type from its exposed parts. In tracing the outcrops of the Lower Carboniferous rocks along the Welsh border it is seen that they form a more or less arcuate front towards the Welsh mass, and gradually turn from a N.N.E to a E.S.E. trend until they become buried in the southern and south-eastern parts of the Midlands. Along the northern side of this semi-arcuate front the coal-basins occur. Further north there rises the Pennine Range. The inference is therefore very natural that these features are but parts of a half buried epsilon system. If so, there must be an eastern wing which would be more or less symmetrical to the exposed western wing with reference to the Pennine axis. It is on this basis that the writer formerly suggested that the axis of the eastern wing cannot be located further south than a line drawn from Warwick to the mouth of the Welland. As the regions to the south of the wings must have undergone considerable compression it would necessarily follow that they must have become either elevated as plateaus or strongly folded in the same trend as the wings. In either case the regions to the immediate south of the inner margin of the wings are not likely to retain any Coal Measures.

All these statements are little more than a theoretical guess. But it is a matter of surprise how they essentially fall in line with the conclusions reached by the painstaking work of Dr. Rastall. The two methods of approach are entirely independent of each other, yet the results obtained are singularly alike.

Judging from the available data, it would seem that the innermost or the northernmost point on the apical line (a line connecting the apices of the successive arcs) of the system cannot be located much further south than Burford in Oxfordshire, for it is almost exactly on the line of the Pennine axis, and a boring record shows that Coal Measures there are thin and unpromising.

Stress is also laid by Dr. Rastall on the Melton Mowbray and the Market Harborough axes, which run in an E.N.E. direction. Citing Thorpe and Rücker and Cox and Trueman, the same author further adds that the post-Triassic or rather post-Lower Jurassic anticline of Melton Mowbray probably rests upon a more pronounced anticline of Pre-Permian date, and, according to Cox, it is probably continued into the area of the Wash. In conclusion, Dr. Rastall says: " On the whole it seems probable that the south-east limit of this fold system (Market Harborough anticline) is quite near to the north-west margin of the Palaeozoic Plateau [of south-east England], and therefore there cannot be much, if any, room for coal-basins between them." In another place he remarks : " As to the tectonic relation of this feature, it can only be said that it has not yet been found possible to bring it into harmony with any of the known trend-lines of this part of England." In the conception of the epsilon structure, these are precisely the features required to complete the epsilon system. They have appeared in their right place and in the right trend.

The presence of the Charnian axes in the Midlands certainly brings in a disconcerting factor. But it is believed that these ancient directrices can only affect the minor divisions of the coal-field within the arcuate front of the epsilon or within its eastern wing, and probably does not play any important rôle in determining the general lie of the coalfield which in that part of England must be essentially, if not solely, controlled by the inner margin of the eastern wing of the epsilon system.

As regards the alleged presence of local anticlines of Charnoid trend inside of the eastern wing, such as those in the Vale of Moreton, Winchcombe, Banbury, Weedon, etc., as named by Cox and Trueman, a feasible explanation may be sought in the secondary " corrugation " due to the horizontal bending of a corrugated surface, to borrow the word from Dr. Rastall. The process can be easily tested by experimental means. If we take a sheet of highly plastic material, for instance, exceedingly fine clay kneaded with water into a suitable consistency, and let it be folded ; then bend the fold horizontally into an arc, corrugation will at once appear on the concave side of the arc. It would seem, therefore, not altogether proper to correlate those local flexures as pointed out by Cox and Trueman with the Charnian folds.

Finally, a few words must be said of the radiating lines of disturbance within, and in some case across, the arcuate front of the epsilon. To understand the mechanical meaning and consequently the tectonic significance of these lines, it would seem necessary to distinguish whether they are folds or faults. The majority of the cases described by Dr. Rastall appear to be faults or folds accompanied by faults,[1] e.g. the Nuneaton line, of which the writer happens to have some slight knowledge.

Now it is a quite usual phenomenon that faults of greater or lesser magnitude cut more or less perpendicularly across the wings of a compressed epsilon. Numerous examples of such " cross faults " are found in the epsilon of Eastern China already referred to. They express the natural consequence due to shearing movement. Whether this is the case with the English epsilon the writer would not venture to say. But the point would certainly seem worthy of further consideration in connection with the discussion of the structure of the coal-basins of the English Midlands.

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[1] *The Tectonics of the Southern Midlands*, 214–17.

As stated before, the writer would not, and is certainly not in the position to, discuss in positive terms any such detailed structures as those referred to in the foregoing paragraphs. With regard to the major issue of the problem, the inclination is, however, strong to join Dr. Rastall in striking out as barren ground that triangular area of south-eastern England which is bounded on the north-west by a line drawn from the south of Burford past Market Harborough and finally to the Wash, and on the south by a line which probably runs more or less in parallelism with, but at some distance to the north of, the Pembroke-Radstock line and its eastern extension in Kent.

Notes on the Portsoy Coastal District.

By Gertrude L. Elles, D.Sc.,

Newnham College, Cambridge, Lecturer in Geology, University of Cambridge.

During the summer of 1928 I spent a month making a detailed study of the metamorphic condition of the rocks in the magnificent section displayed along the Banffshire coast and in the immediate hinterland, and this work has been supplemented by examination of a number of rock slices cut from specimens then obtained, and also of those in the collection of the Sedgwick Museum mostly collected by Mr. Harker.

From the point of view of progressive regional metamorphism the sections seen along this coast are of considerable interest and importance, since the section is almost continuous at low tide between Gamrie Bay on the east, and Findochty on the west, and the metamorphism is seen to range from nearly the lowest grade (chlorite) to that of the highest grade (sillimanite) as at present recognized and defined (1).[1] Whilst in general the value of staurolite as a grade index is open to question, since it seems to demand rather peculiar conditions for its formation outside those of a normal pelitic series (2), and hence it is possible to have continuous progressive metamorphism in which the Staurolite Zone may be omitted, nevertheless when present its place seems to be between that of Kyanite on the one hand and Garnet on the other as was noted years ago by Barrow (3).

Traced E. to W. along the coast the metamorphism rises in general, first to the grade of the Garnet Zone, though the effects of the regional metamorphism are overshadowed in places by a metamorphism approaching in character to that more usually associated with contact metamorphism, except that here the rocks affected are not always connected with visible outcrops of igneous rocks ; the grade then changes abruptly to that of the Sillimanite Zone, and thence declines more or less steadily to the west till the grade of the Garnet Zone is reached again. Together with these effects of regional metamorphism there are in this western area also associated effects which may be interpreted as due to contact action since they occur in the vicinity of outcrops of igneous rocks.

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[1] For Bibliography see end of paper.

The general stratigraphy of the whole section has been dealt with in the Geological Survey Memoir (4), but whilst in some cases my work supplies supplementary details to the results already given, in other cases I find myself unable to agree with the description of the rocks there recorded and the conclusions deduced therefrom. The part of the coast section with which the present paper deals ranges from Boyne Bay to Findochty, where the following rock groups are exposed. The classification is that adopted by the Geological Survey.

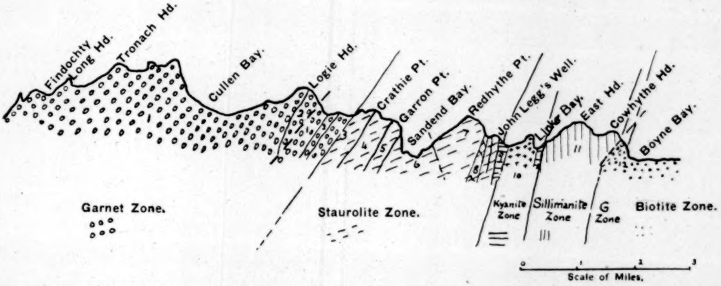
Findochty
Long Hd.
Tronach Hd.
Cullen Bay.
Logie Hd.
Crathie Pt.
Garron Pt.
Sandend Bay.
Redhythe Pt.
John Legg's Well.
Links Bay.
East Hd.
Cowhythe Hd.
Boyne Bay.
1
2
3
4
5
6
7
8
9
10
11
12
Garnet Zone.
Staurolite Zone.
Kyanite Zone
Sillimanite Zone
G Zone
Biotite Zone.
0
1
2
3
Scale of Miles.

FIG. 1.—Map of coastal area between Boyne Bay and Findochty to show grades of metamorphism. 1, Cullen Quartzite. 2, Westsands Group. 3, Findlater Flags. 4, Crathie Point Group. 5, Garron Point Group. 6, Sandend Group. 7, Durnhill Quartzite. 8, Older Granite. 9, Portsoy Group. 10, Older Basic Rocks. 11, Cowhythe Gneiss. 12, Boyne Limestone.

BANFF DIVISION.
Whitehills Group
Boyne Limestone.

KEITH DIVISION.
Cowhythe Gneiss
Portsoy Group
Durn Hill Quartzite
Sandend (Black Schist and Limestone) Group
Garron Point Schists
Crathie Point Calcareous Group
Findlater Flags
West Sands Group
Cullen Quartzite.

The general dip of the beds is in a S.E. direction, but by no means invariably so, and the location of the N.W. dips, usually in the beds with the greater resistance to the folding stress, gives a more correct idea of the folding and packing that has taken place; there is indeed every indication that the rocks lying in between the Gneiss and the Quartzite outcrops have been very much crushed and packed into a series of steep isoclines, and this folding has been shared in a somewhat lesser degree by the more resistant beds which reveal

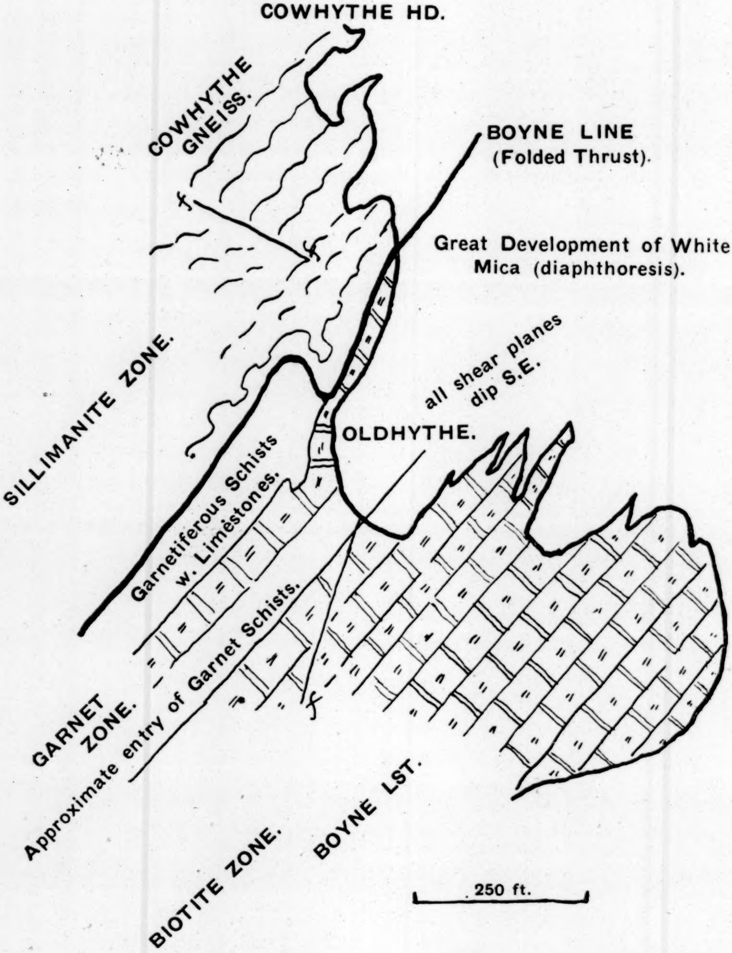
COWHYTHE HD.
COWHYTHE GNEISS.
BOYNE LINE
(Folded Thrust).
Great Development of White Mica (diaphthoresis).
all shear planes dip S.E.
SILLIMANITE ZONE.
OLDHYTHE.
Garnetiferous Schists w. Limestones.
Approximate entry of Garnet Schists.
GARNET ZONE.
BIOTITE ZONE.
BOYNE LST.
250 ft.
f
f
f

FIG. 2.—Rough sketch-map of coast near the Boyne Line to show relation of biotite, garnet, and sillimanite zones.

it in their N.W. dips. Hence it is possible to detect definite anticlinal structures in the Cowhythe Gneiss east of East Head, in the Durnhill Quartzite at Redhythe Point, in the Flaggy Beds of Crathie Point, and in the Cullen Quartzite west of Logie Head, whilst an obvious syncline is developed in this last rock near Tronach Head.

Attention may first be drawn to the rocks lying on either side of the much discussed BOYNE LINE. There is undoubtedly a great hiatus here as regards metamorphic condition, between the rocks on either side of this line of disturbance, but it is not quite so great as the description of the rocks in the Survey Memoir would lead us to believe. The rocks lying to the east of the Boyne line are described by the use of that much abused term " phyllite ", which conveys to many people an idea that the beds are in a low grade of metamorphism, that is not the case ; whilst the whole of the Whitehills Group reaches the grade of the Biotite Zone only, the grade increases steadily throughout it in a westerly direction till the Boyne Limestone is reached ; the structurally highest portion of this group is also in the Biotite Zone, but garnet makes its first appearance about the middle of the cove known as Old Hythe ; at first the crystals are small and sporadic, but closer to the Boyne line garnet is fairly abundant. In a slice made from the rocks at this locality the schist is seen to be very richly micaceous, being crowded with flakes of red brown biotite growing in regular parallel fashion : the garnets themselves show a tendency to linear grouping, and are for the most part small and rather irregular in shape, though a few show some indication of definite crystal outline. These rocks then must be considered to have reached the grade of the Garnet Zone.

The Boyne Limestones and Schists are very highly contorted in the immediate neighbourhood of the line of disturbance, which has all the appearance of a folded thrust plane.

The rock group termed the Cowhythe Gneiss (largely a series of paragneisses and schists) is undoubtedly in a very much higher grade of metamorphism, belonging apparently to the Sillimanite Zone, though sillimanite is by no means universally present. Originally this group of rocks must have been for the most part a series of sandy flagstones or flaggy sandstones with a variable content of quartz and felspar. In their present metamorphosed condition the rock types seen appear to be related not only to their original composition, but also to their position in relation to planes of movement and to certain masses of the Older Igneous rocks. The very coarse type of the Gneiss noted by the Survey (p. 44) as being a gneiss with much mica and pink felspar " ovals " is an unusually felspar-rich type ; in a specimen taken a little E. of East Head scarcely any quartz is present, and the rock consists mainly of fairly large and fresh crystals of oligoclase and red-brown biotite with good pleochroic haloes ; sphene is abundant in granular masses, and apatite and tourmaline are abundantly represented. A second type, which is very common, contains very little felspar and is mainly a puartz-biotite-schist with subordinate crystals of felspar, mainly oligoclase ; the rock at Cowhythe Head is noteworthy in that orthoclase is the most abundant felspar and contains large rounded inclusions of quartz : it also contains red-brown biotite and some iron ore. Sillimanite needles may be sparingly present in both these last types. White mica occurs somewhat sporadically, but is abundant in certain places where it is developing conspicuously at the expense of the felspar, and as this change is characteristic of the rock in places where there is other evidence of considerable movement, it is almost certainly a breaking-down effect and to be connected with such movement. It is only a characteristic feature of the Cowhythe Gneiss near the thrusts. Thus between the Boyne Line and Cowhythe Head it is abundant, and again on the E. side of Links Bay, where there is to be found the structure which I have termed the Portsoy Thrust.

The Cowhythe Gneiss below the Rope Walk on the east side of Links Bay is a garnetiferous-biotite schist very rich in sillimanite.

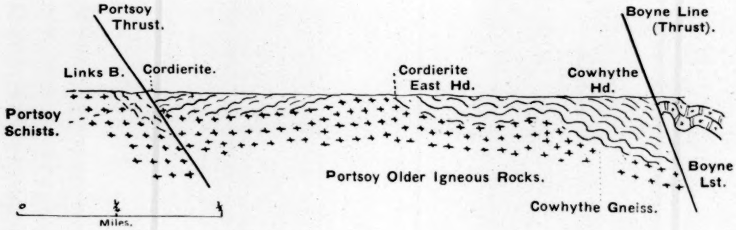

FIG. 3.—Diagrammatic section to show possible relationship of Cowhythe Gneiss to Portsoy igneous rocks.

This rock from its position must be very closely associated with the cordierite-sillimanite gneiss described in the Survey Memoir (p. 148) but I have not detected any cordierite in this actual rock ; the suggestion that this abundance of sillimanite and cordierite may be ascribed to the contact action of the Portsoy Older Igneous rocks finds confirmation in the occurrence of a very similar rock, which has now been found in close association with the serpentine of East Head ; in this rock the cordierite is even more abundant and the crystals larger, though the pleochroic haloes are less obvious than in the Links Bay specimen. In the East Head rock, quartz and felspar are about equally abundant the latter being represented by both orthoclase and oligoclase ; large apatite crystals are developed and sillimanite occurs in well defined crystal groups. The occurrence of cordierite and the richness in sillimanite at these two localities may be attributed to an intensified metamorphism, where probably owing to the combined effect of depth and very high temperature, partly the result of the intrusion of the igneous magma, a degree of plasticity would be attained so that any stress effect would be reduced to a minimum.

Another feature of interest may be noted on the east side of Links Bay suggesting that the line of junction of the Cowhythe Gneiss is along a line of movement, which for the sake of convenience may be termed the Portsoy Thrust. There is a mention in the Survey Memoir (p. 44) of a " small fault running N.N.E. to S.S.W." but it is I think a structure of more importance than is suggested at first sight. It can only be seen properly at low tide and apart from the actual place where the quartzites and limestones of the Portsoy Group are brought against the Cowhythe Gneiss there is no striking contrast in outward appearance as regards the pelitic members of either group, the schists of both looking very much alike. Close observation, however, shows that there is marked shearing all along

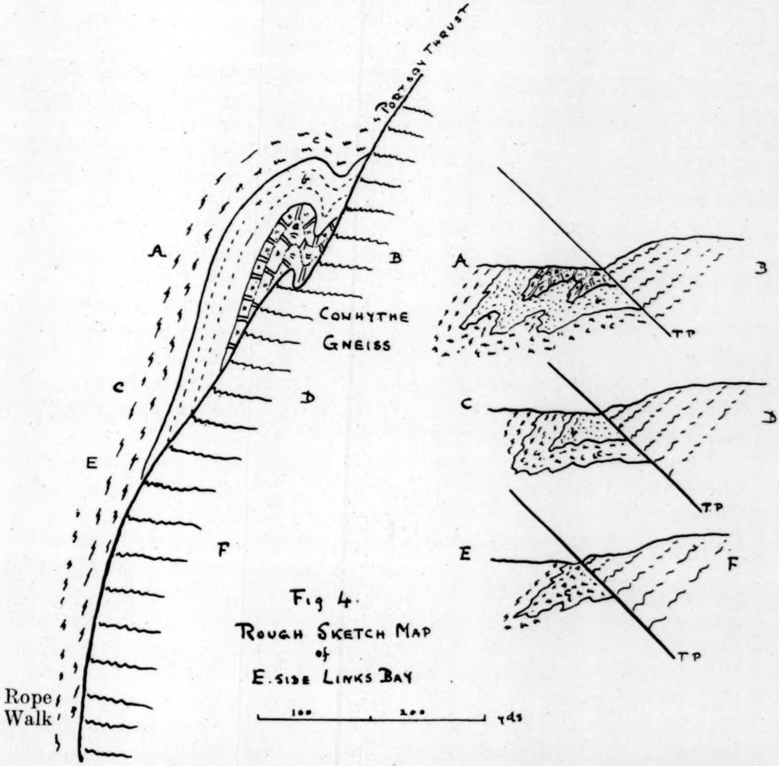

FIG. 4.—PORTSOY GROUP.—*a*, Limestone and Calcareous Schists. *b*, Quartzite and Quartz Schists. *c*, Schists. These rocks are far more crushed and broken than shown.

this line, which is somewhat irregular in trend and slightly folded as indicated in the accompanying sketch-map (Fig. 4).

The reasons for regarding this line of disturbance as important may be summarized as follows :—

The quartzites, limestone and schists of the Portsoy Group have no real continuity with the Cowhythe Gneiss other than that imposed upon them by the later folding of the thrust plane which they share ; on the contrary the strike of the Portsoy Beds is such as to run in places at right angles to the Cowhythe Gneiss ; the Cowhythe Schists at this locality appear to be dipping at a high angle to the N.W. and in the actual vicinity of the thrust are approximately vertical though much contorted in detail. The limestone, quartzite and schists of the Portsoy Group run very irregularly : they may strike dead at the Cowhythe Gneiss at a high angle of inclination, be lying almost flat at another place, or for a short distance run practically parallel with the Cowhythe Gneiss (see Fig. 4.) The limestone, quartzite, and schists die out in turn against the Gneiss as shown in the sketch-map. Moreover there is here a slight hiatus in metamorphic grade ; with one exception to be noted later, sillimanite is not found west of this line, and the suggestion here made is that this Portsoy Thrust represents a line of movement roughly parallel with the Boyne Line, between which the Cowhythe Gneiss has been thrust upwards to form a somewhat complex anticlinorium, the rocks here seen really belonging to a somewhat deeper zone than their present position with regard to the other rock groups. This upthrust is combined with a slight overdrive towards the N.W. so that the members of the Portsoy group which should share this high grade of metamorphism are buried beneath the Cowhythe Gneiss. (see Sections, Fig. 4).

In its general effects this Portsoy Thrust has much in common with that of the Boyne Line, but these are of a slighter order.

The next point concerns that member of the Portsoy Group which has been described as a " chiastolite slate " (p. 147) and also as an " andalusite staurolite schist " (p. 37).

It is not easy to understand why this rock was ever termed a " chiastolite slate " unless the wish was father to the thought, for there seems to be no cleavage, and though of rather irregular texture and somewhat crushed, it is none the less definitely foliated with irregular porphyroblasts of white mica disseminated through it. Under the microscope the foliation is very distinct and the rock obviously one in a high grade of metamorphism.

Being unable to detect any chiastolite in the slices cut from my own specimens, though both staurolite and kyanite were abundantly present, I obtained permission to examine the rock slices in the collection of the Geological Survey, and was then forced to the conclusion that the mineral described as chiastolite (or andalusite) should more correctly be referred to kyanite, since there does not seem to be any chiastolite in the rock, though there is a great deal of kyanite, of which no mention is made in the **Memoir** in the description of the rock slices 3,151, 3,152, and 15,497.

There can I think be little doubt as to the identification. The crystals show a good cleavage parallel to 100, a less perfect one parallel to 010, and a parting parallel to 001; the crystals moreover sometimes show good twins with composition plane 100, and longitudinal sections show that Z lies parallel with the cleavage and not across it as in andalusite. Some sections naturally show practically straight extinction, but many are oblique with a maximum extinction angle of 30° ($Z \wedge c$).

Hence this mineral differs from andalusite in cleavage, extinction, twinning, and character of elongation.

The relationship of this kyanite to the porphyroblasts of white mica is perfectly obvious; in the rock slice these are seen to be pseudomorphs-in-the-making after kyanite; whilst it is true as has been noted in the Memoir, that in some cases the pseudomorphs are complete and little or nothing remains of the original mineral, in other cases there is a central core of kyanite with a bounding rim of white mica into which the kyanite fringes out, and in others again but a slight change has occurred though there is a slight tendency to fringing out at the periphery of idioblastic crystals. To describe what is seen as 'the chiastolite (sic) is entirely replaced by rather large scales of white mica with a little quartz' is hardly consistent with the facts. Moreover the reputed "cross shaped inclusions" upon which so much faith has been placed seem to exist more in fancy than in fact. There is sometimes a collection of inclusions running in a band right through the crystal in one direction or the other, and sometimes there are irregular patches; but as a rule there is no approach to regularity, and the idea conveyed is merely that of the gradual growth of a crystal absorbing material from the surrounding matrix in the process of its growth. I have been unable to find anything approaching the regularity of grouping found in chiastolite in either my own slices or those of the Survey collection, the nearest approach being a rather half-hearted attempt in a cross section whose form suggested staurolite.

Therefore the interest attached to the rock on account of its supposed content of andalusite, which might be held to imply an effect of contact alteration by the Older Igneous rocks, disappears, since the rock is merely a garnetiferous staurolite-kyanite-schist similar in its general characters and grade of metamorphism to those members of the Portsoy Group seen inland in the Braco burn and the Limehill burn where no question of contact alteration comes in.

Westward, staurolite is still abundant in the Graphitic Schists of the Cove of John Legg's Well, and here rhombic cross-sections of the mineral are of fairly common occurrence, but no kyanite has been seen here. So presumably the metamorphic grade is diminishing slowly. That this is the case seems to be borne out by the fact that sillimanite has been recorded by the Geological Survey on the E. side of Redhythe Point where it occurs in a pelitic band in the Durnhill Quartzite in the vicinity of the Older Granite intrusion of Boggierow. The general grade is continuing so high that it merely required the additional heat of the granite magma to produce the mineral characteristic of the highest grade of metamorphism.

This is further evidenced by the metamorphic condition of the beds still further west in Sandend Bay, at Garron Point and at Crathie Point. On the E. side of Sandend Bay in the Black Schists above and below the fifth limestone of the Sandend Group, staurolite is still an abundant mineral though the crystals are becoming smaller and are rarely conspicuous in a hand specimen. Staurolite continues to be found as far west as Crathie Point, but many of the schists between Sandend Bay and Crathie Point belong to the calcareous rather than the pelitic facies, and hence show a different mineral assemblage, the most characteristic mineral here developed being the tremolite which is abundant and often shows beautiful radiating or feathery groups.

Kyanite has been recorded from the E. side of Crathie Point in the Survey Memoir. I have not detected this mineral myself, but should be quite prepared to see it in the rocks belonging to the heart of the anticline which occupies the area between Garron and Crathie Points since such rocks might be expected to be in a slightly higher grade of metamorphism, and I have noted a similar occurrence in some sections inland.

The Findlater Flags to the west again are not of the type to show much variation in mineral composition, but have been found to show garnets in some of the more pelitic beds, and nothing has been seen westward of Findochty Castle to suggest that the beds are anywhere in a higher grade of metamorphism than that of the Garnet Zone. Garnets are everywhere a conspicuous feature in the rocks of the West Sands Group and in a rock slice these are seen to be large and well formed for the most part, and together with quartz form eyes in the schist round which the bands of biotite and muscovite are bent. Still further west the pelitic bands in the Cullen Quartzite yield a plentiful crop of garnets well seen all round Findochty, especially near Long Head.

Thus the evidence afforded by the metamorphic condition of the rocks of the Portsoy coast district and its immediate hinterland suggests that the rocks have been folded into an anticlinorium whose eastern margin is now overthrust along the Boyne Line. This type of structure, whatever be its part in the larger structural history of the Highlands, is well-known in other Highland areas. It is found in the Schichallion country in advance of the Loch Tay Thrust, in the Glen Lyon country west of the Bridge of Balgie Thrust, and in the country west and north of Loch Lyon in advance of the Ericht-Tyndrum Thrust.

The evidence both from the distribution of the beds and their metamorphic condition suggests that in response to powerful impulses from the S.E. there were developed anticlinal structures of a large order (probably somewhat overturned to the N.W.) and that as the impulses continued and strengthened these were eventually ruptured by the great lines of thrusting and dislocation that are now so obvious a feature of Highland geology. This idea carries with it the suggestion that the Boyne Line is a thrust of similar nature to these other Highland structures and a relatively late feature in the structural history of the area.

With regard to the rather dangerous subject of correlation some general remarks may be offered on the basis of the study of the different groups of Highland Schists in varying degrees of metamorphism, and their field relationships. The author finds she is in agreement with the late Dr. Horne (5) as regards the eastern part of the area. The Boyne Limestone certainly recalls certain aspects of the Loch Tay Limestone and may well represent that horizon, and the groups lying to the east might well represent the Pitlochry Schists, Ben Ledi Grits, Aberfoyle Slates, etc.

She also agrees in *principle* with the correlation of the members of the Keith Division as given by Dr. Read (6), but would group the various members rather differently. She considers that the Portsoy Group may represent both the Beinn Eagach Group (Beds of John Legg's Well) and the Ben Lawers Schists, some of which are concealed by the Portsoy Thrust. This would leave the Cowhythe Gneiss as the representative of most of the Ben Lui Schists and the Sròn Bheag Schists, which they might well be from the point of view of composition taking into account the increased grade of metamorphism. She feels also that possibly the Garron Point Beds may belong to the Blair Atholl Group but that is a matter of detail.

The correlation which she would suggest as a possible one would then be as follows :—

Cullen Quartzite	=	Glencoe Quartzite.	
West Sands Group Findlater Flags Crathie Point Group	=	Leven Schists.	
Garron Point Group Sandend Group	=	Blair Atholl Group.	
Durn Hill Quartzite	=	Central Perthshire Quartzite.	
Portsoy Group		Beinn Eagach Schists. Ben Lawers Schists.	
			Portsoy Thrust.
Cowhythe Gneiss	=	Sròn Bheag Schists. Ben Lui Schists.	
			Boyne Thrust.
Boyne Limestone	=	Loch Tay Limestone.	

The author wishes to express her indebtedness to the Director of the Geological Survey for permission to examine specimens and rock-slices in the Survey Collection, to Dr. Tilley for his ever-ready help and criticism, and to Miss Elinor Gardner for much assistance in the field-work.

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(3) G. Barrow, 1893. "On an Intrusion of Muscovite-Biotite-Gneiss in the S.E. Highlands and its accompanuing Metamorphism," *Q.J.G.S.*, xlix, 330.

(4) *Memoirs of the Geological Survey of Scotland*, 1923, "The Geology of the Country round Banff, Harlty, and Turriff," 11 *et seq.*

(5) Ditto, 72.

(6) Ditto, 71.

Mountain and Island Arcs.

By Philip Lake, M.A., F.G.S.

In a recent number of the *Records of the Geological Survey of India*, vol. lxii, p. 410, Dr. Fermor has done me the honour to draw attention to a paper of mine (Geological Magazine, 1903, p. 305) in which I came to the conclusion that the thrust-plane at the base of the Himalayas must have, at its outcrop, a dip of about 14°; and he points out that this estimate agrees with the observations of Mr. Middlemiss in Jammu Province. My estimate was based upon a simple geometrical deduction which proceeds directly and inevitably from the assumption that the Himalayas rest upon a plane thrust-surface.

When the paper was written the thrust-planes of the Subhimalayas were always represented as dipping at a high angle. Accordingly I supposed that they were not basal planes, but were comparable with the minor thrusts of the North-west Highlands, though very much greater; and I imagined that the real basal thrust-plane must lie below. In the Jammu Province, however, where he had contoured maps at his disposal, Middlemiss[1] found that the dip of the thrust-plane between the Murree Beds and the Siwaliks was 12°–15°. This, as Fermor says, is the main boundary fault, which can be traced for some 1,500 miles; and Middlemiss, from his experience in Jammu and elsewhere, thinks it most likely that in other parts of the Himalayas, where no contoured maps are available, its dip has been greatly over-estimated.

The primary object of my paper was to suggest a simple explanation of the fact that many mountain chains and island festoons are very precisely arcs of circles, a fact which Professor Sollas had emphasized in his paper on "The Figure of the Earth".[2] A thrust-plane which is really a plane must crop out in a circular arc upon a globe; and it is not a far-fetched notion to imagine thrust-planes at the bases of the submerged ranges which form the island arcs off the coast of Asia. It is evident, however, that some of Professor

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[1] *Rec. Geol. Surv. India*, l, 122.

[2] *Quart. Journ. Geol. Soc.*, lix, 1903, 180.

Sollas's small circles, less convincing than these, belong to a different category. No one is likely to suppose, for example, that the west coast of North Africa is the outcrop of a thrust-plane.

There was another point in Professor Sollas's paper which led me at the time to a further deduction. I recognized, however, that in default of actual field evidence my conclusion with regard to the Himalayan thrust-plane would not appeal to the geologists of the day with the same force as to myself; and it seemed useless to proceed to a more complex deduction. Perhaps now it may be worth consideration.

Professor Sollas finds that the centres or, more correctly, the poles of several of his small circles lie upon the same great circle. His small circles are drawn to complete arcs formed by geographical features such as the Aleutian Islands. If the arcs which have their poles lying upon the same great circle are the outcrops of thrust-planes, it follows at once that these thrust-planes are all at right-angles to the plane of that great circle.[1] Movements upon the thrust-planes in a direction at right-angles to the plane of the great circle will be parallel, and a mass limited by a system of such thrust-planes may move as a whole upon them. If, on the other hand, the thrust-planes which limit the mass are not at right angles to some single plane, it will be impossible for the mass to move upon them without breaking up, and this will require an extra expenditure of energy.

At the inception of a great movement of this type the fractures are no doubt numerous, small, and irregular; but the fact that parallel movement is the easiest will lead to the selection of those fractures that allow such movement, and they will tend to become predominant.

This was the explanation that occurred to me, but the method of determining the poles of his small circles used by Professor Sollas is not altogether satisfactory. If an arc is linear and extends through a great part of the semi-circle, as in the case of the Aleutian Islands, its pole may be found precisely enough by trial with a pair of compasses upon a terrestrial globe ; but few island or mountain arcs are so suitable for the method as this. Some, like the Kurile Islands, are as linear, but stretch through a much smaller part of the circle ; others, like Japan, are broad belts with irregular edges, and have no definite centre. In the former case a more exact method of determining the position of the pole is required, in the latter a more precise definition of the arc.

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[1] The following considerations may help those who are not familiar with the geometry of the sphere. If the plane of any circle upon a sphere passes through the centre of the sphere the circle is a "great circle", otherwise it is a "small circle". On an ordinary globe the meridians and equator are great circles, the parallels of latitude, except the equator, are small circles. The pole of a small circle is a point on the surface of the sphere which is equally distant from every point of the circle, and it bears precisely the same relation to the small circle that the geographical pole does to a parallel of latitude. In each case there are two opposite poles, but we need only consider the one nearest to the small circle in question. It will be evident to everyone who looks at an ordinary geographical globe that the plane of any parallel of latitude is at right angles to the planes of the meridians, i.e. to the planes of all the great circles that pass through the geographical pole. In the same way the plane of any small circle is at right angles to the planes of all the great circles that pass through *its* pole. When two or more small circles have their poles upon the same great circle, the plane of each small circle is at right angles to the planes of all the great circles passing through its own pole; and therefore the planes of all the small circles are at right angles to the plane of the one great circle that passes through the poles of them all.

If the small circles and their poles are to have any geological significance, the circles must be related to geological rather than to topographical features, and the poles must be determined with greater precision than is usually possible upon a terrestrial globe, even of large size. Owing to the distortion which is necessarily involved when a spherical surface is represented upon a flat one it is not possible to find the poles, either by trial or by geometrical construction, upon any ordinary map. On a stereographic projection it would be possible, but that projection is never used for maps except, occasionally, for small maps of the hemispheres.

I have, therefore, adopted a different procedure. In the case of each of the arcs examined, the first step was to select the best geological line that the information at hand allowed ; the second, to determine on a large scale atlas-map the latitude and longitude of three points on this line, one at each end and one in the middle ; the third, to compute from these data the latitude and longitude of the pole of the small circle passing through these three points, and also the radius of the circle. Apart from its preciseness, the method has the advantage, very great where questions of coincidence are involved, that self-deception is impossible. When obtaining his data the worker does not know what results will follow.

None of Professor Sollas's great circles satisfied me, but the island festoons off the east coast of Asia are so nearly arcs of circles that it seemed likely that they owe their form to thrust-planes. The basal thrust-planes must be beneath the sea, but it may reasonably be expected that the main tectonic lines which appear above the water will be approximately concentric with the outcrops of those planes, and it was accordingly worth while to apply the method just described. The arcs examined were the Kurile Islands, Japan, the Riu Kiu Islands and the outer arcs of the Philippine Islands.

The Kurile arc is a clearly defined volcanic chain, linear enough and sufficiently close to a circular arc to offer no difficulty.

The Japan arc is the least satisfactory of the four. Both topographically and geologically it has a distinct elbow about Tokyo, and at this elbow the *Fossa magna* of Naumann crosses and disturbs the tectonic lines, so that they are not truly circular. The best I could do was to take three points on the great fault or thrust-plane[1] which follows the longitudinal depression of Honshiu and Shikoku, avoiding the disturbances near the *Fossa magna*.

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[1] I took the line of the fault from Richthofen's tectonic sketch-map of Japan in *Sitz. d. k. preuss. Akad. Wissensch.*, 1903, 894.

The Riu Kiu arc is divided by Richthofen[1] into three zones, Volcanic, Palaeozoic, and Tertiary, of which the last is on the outside of the curve. My three points are upon the outermost islands of the group, selected as marking the outer limit of the Tertiary zone. In the *Times Atlas* the islands on which these three points lie are called Tanega Shima, Kikai Shima and Hateruma Shima.

For the Philippine arc I selected the most complete of the tectonic lines shown in the map, after W. D. Smith and S. Masó, reproduced in the French edition of Suess's *Das Antlitz der Erde*, vol. iii, p. 1395. This is the line which runs from one of the southern peninsulas of Luzon, through Masbate and Leyte, into the east of Mindanao.

The geological lines here indicated were taken as representing the arcs. Upon each line three points were selected and their latitudes and longitudes[2] determined from the largest-scale map available in Stieler's *Handatlas* (for the Kurile arc) or the *Times Atlas* (for the other arcs). From these data the positions of the poles of the arcs were computed and also the lengths of their radii in degrees and minutes of a great circle, with the following results :—

	Pole.		*Length of*
	N. Lat.	*E. Long.*	*radius.*
Kurile arc . . .	55° 23′	135° 47′	13° 2′
Japan arc . . .	40° 16′	133° 4′	6° 26′
Riu Kiu arc . .	32° 9′	121° 19′	8° 25′
Philippine arc . .	5° 13′	115° 55′	10° 23′

If we draw a great circle passing through the Kurile and Philippine poles, the arc of this circle which is included between these two poles is about 52½°. The Riu Kiu pole lies 1° 53′ from this great circle, upon its western side. The Japan pole lies 4° 28′ from the great circle, upon its eastern side.

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[1] *Sitz. d. k. preuss. Akad. d. Wissensch.*, 1902, pl. iii. The map is reproduced in the French edition of Suess's *Das Antlitz der Erde*, iii, 1401.

[2] To avoid encumbering the text with figures which are only of use to those who wish to check my calculations I give here the latitudes and longitudes of the points selected in each arc.

Kurile arc . . .	50° 0′ N.	155° 29′ E.
	45° 54′	150° 0′
	43° 56′	145° 30′
Japan arc . . .	40° 33′ N.	141° 30′ E.
	34° 31′	136° 43′
	33° 50′	132° 46′
Riu Kiu arc . . .	30° 35′ N.	131° 0′ E.
	28° 20′	130′ 0′
	24° 2′	123° 50′
Philippine arc . .	13° 15′ N.	122° 35′ E.
	10° 25′	125° 0′
	6° 45′	126° 15

It is easy to verify all these results approximately upon a good terrestrial globe with a pair of compasses and a piece of thread. To save as much trouble as possible to those who wish to check the calculations I have only to add that the pole of the great circle which passes through the Kurile and Philippine poles lies at 14° N. Lat., 24° 36¾′ E. Long., to the nearest quarter-minute.

In the circumstances the results cannot be conclusive. They are based, not upon the basal thrust-planes themselves, but upon geological features generated by the movement along those planes. To my mind the fact that the poles of these features lie so nearly upon the same great circle suggests that the poles of the thrust-planes themselves lie equally near and very likely nearer. If they *do* lie close to the same great circle, then the mass of Asia has behaved as a single unit. Either it has been thrust over the Pacific floor or the Pacific floor has been thrust under it. Since there is also "overthrusting" southwards along its southern margin, the latter is, on the whole, more probable. The simplest explanation is to assume that the Asiatic mass, excluding the peninsulas of Arabia and India, remained unmoved and underthrusting took place from both oceanic sides.

This conception harmonizes either with the contraction theory or with Joly's theory. According to the latter the under-thrusting would occur during the consolidation of the sima and the sinking of the ocean-floor. According to the former, the contraction would be continuous but the actual yielding to the resulting strains would be discontinuous. In either case the process is analogous to the wedging up of the keystone of an arch, or a dome, when it is not sufficiently weighted.

My chief concern, however, is with the nature of the movements rather than their cause ; and my chief hope of further light is that, with the rapid methods of sounding now available, it may not be long before the submarine contours outside the island arcs are known with sufficient accuracy to indicate the outcrops of the basal thrust-planes.

NOTE.—Since this paper was placed in the hands of the Editor, Dr. Vening Meinesz [1] has given, at the Royal Geographical Society, a most interesting summary of the results obtained in his gravity survey of the Indian Archipelago. The gravity anomalies in this region surpass any that had hitherto been observed, and the most remarkable feature is a belt of negative anomaly which lies outside the East Indian arc. As Dr. Meinesz points out, the only plausible explanation is that there is here a downward protuberance of the lighter crust into the denser material below, and this protuberance must be very much greater than the upward protuberance which is visible to our eyes.

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[1] See *Proceedings, Kon. Akad. Wetensch. Amsterdam,* xxxiii, 566–77. The R.G.S. paper is not yet published.

If, as I am supposing in this paper, there is a thrust-plane at the base of the East Indian arc, the phenomenon seems to follow as a natural consequence. When movement takes place upon a thrust-plane, the over-riding part of the crust presses down the part that is over-ridden, thus initiating the depression which is commonly found outside mountain and island arcs. The faulting and folding which takes place in the overthrust mass produces the mountain range upon the surface ; the faulting and folding which takes place in the underthrust mass produces what may conveniently be called a negative mountain range, i.e. a sub-crustal inverted mountain range dipping into the denser material below. The main mass of the superficial range lies far behind the superficial outcrop of the thrust-plane and, similarly, we may expect that the main mass of the sub-crustal range will lie far " behind " (from its point of view) the sub-crustal outcrop of the thrust-plane. The sub-crustal range may, accordingly, be well outside (from the surface point of view) the superficial range. As the movement goes on we may expect that the superficial and sub-crustal ranges will approach each other, but the whole question requires more detailed consideration than is possible in a short note.[1]

The inevitable attempt at isostatic equilibrium will necessarily make the sub-crustal range by far the greater and more massive of the two.

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[1] A point to which it may be well to draw attention at once is that while the front of the overthrust mass is convex towards the direction of overthrusting, the front of the underthrust mass will be concave towards the direction of underthrusting.

REVIEWS.

The Structure of Asia. Edited by J. W. Gregory. vi + 227 pp., with 23 plates and 17 figures in the text. London: Methuen and Co. 1929. 10*s*.

THE area of Asia is about 17,000,000 square miles. India has had geologists for a hundred years and a Geological Survey for nearly eighty, but, with its dependencies, it occupies less than 2,000,000 square miles. For our knowledge of the remaining 15,000,000 square miles we are still dependent almost entirely upon exploratory survey. Other Geological Surveys have been established in more recent years, but the areas which they have covered in more than exploratory fashion are still small. Even now it is probable that the number of competent field geologists who have spent more than a few months in the 15,000,000 square miles does not exceed a hundred. This would give an average of 150,000 square miles per geologist, and the area of Great Britain is less than 90,000 square miles. It is curious to reflect that even if there had been a thousand, and each of them had walked 20,000 miles, less than one four-hundredth of the area would have come within reach of their hammers. Perhaps it is too sobering a reflection, for in some parts of Asia the structure is displayed with a clearness that has no parallel in our islands. On the other hand there are many thousands of square miles where it is completely concealed by loose accumulations. For much of the continent not even the guarded conclusions of Suess, much less the imaginative theories of Argand, have any firm foundation.

The title of the volume before us is a little misleading. It is not an account of the structure of Asia, but a series of papers upon the structure of different parts. These papers were originally contributed to a discussion at the meeting of the British Association at Glasgow in 1928. There is little connection between them, and they cover only a fraction of the continent. Professor Gregory, in his excellent introduction, has endeavoured to bind the whole together, but the book remains a collection of fragments. It forms, however, a very useful supplement to the account in *Das Antlitz der Erde*, which is still the best available, but is necessarily out of date in many respects.

The most valuable of the contributions is that upon the Iranian ranges, by Dr. de Böckh, Dr. Lees, and Mr. Richardson, of the Anglo-Persian Oil Company. It occupies more than half the volume, and gives a full summary of the stratigraphy and tectonics of this interesting region. Nowhere is the structure of a mountain range, or its relations to the foreland, more clearly displayed than here; and this chapter alone would make the book indispensable to the student of tectonics.

A short chapter upon the structure of the East Ferghana and Alai ranges in Eastern Turkestan by Professor Mushketov, the Director of the Soviet Geological Commission, will be especially welcomed on account of the inaccessibility of information about these regions. A chapter by Professor Barbour on the structural evolution of Eastern Asia, and another by Professor Berkey on orogenic evolution in the Gobi region are of quite a different type. They are not concerned with details, but with the conclusions that may be drawn from them. Those conclusions are necessarily tentative, but they are interesting.

Two very short notes upon the North-west Himalaya and the East Indian Islands complete a work which is certainly not a balanced account of the structure of Asia, but is nevertheless a useful volume. P. L.

THE GEOLOGY OF THE MARYPORT DISTRICT. Expl. Sheet 22, *Mem. Geol. Survey.* By T. EASTWOOD. Pp. viii + 137, with 3 plates and 19 text-figures. 1930. Price 3*s*.

AS is natural the greater part of this memoir is occupied by a detailed discussion of the Carboniferous system, but other features receive adequate treatment, though we are given only somewhat tantalizing glimpses of the Skiddaw Slates and the Cockermouth lavas. The assignment of the latter to the base of the Carboniferous is a recent discovery, hitherto, we believe, only revealed in the *Summary of Progress*. The account of the glacial deposits is of much interest, especially as regards the extraordinary variety of erratics found in some localities. Ice flow from the Lake District must have been a very complicated affair. The author is to be much congratulated on the successful completion of what appears from the Preface to have been a single-handed piece of work, except for palaeontological assistance.

THE MODERN DOWSER. By the VICOMTE HENRY DE FRANCE, translated by A. H. BELL. ix + 135 pp., with 2 plates and 11 figs. London: G. Bell and Sons, Ltd. 1930. 3*s*. 6*d*.

THE art of "dowsing" or prospecting for water, minerals, and other things, is a subject of very great interest to those who possess an open mind, and are not bounded by dogmatism. It is not sufficient to dismiss it with a sneer or an imputation of deliberate fraud, as has usually been done in "scientific" circles. In this connection during past years some eminent geologists have not been conspicuous for a dispassionate consideration of undoubted facts in need of explanation. The exponents and supporters of dowsing in general have undoubtedly damaged their own cause by the extravagance of their claims, and in this respect the book now under review is disappointing; it is to be feared that it will not do much to help on a reasonable explanation of the striking results in water-finding that appear to have been obtained by some of the more moderate practitioners in the art. The author, while recognizing the value of the rod, pins his faith on the use of a "pendulum" as he calls it; a small weight, one or two ounces only, at the end of a few inches of string, which is supposed to vibrate or gyrate according to circumstances, when held in one hand, while its performances are assisted by pointing with the other hand. It is obvious that such a pendulum would be greatly helped by slight movements, conscious or unconscious, and such an apparatus seems on the face of it to be far too much subject to the personal equation to be of any value as a scientific instrument. When we find the author claiming to be able to determine the degree of purity of water by tying a bit of blue ribbon to a black pendulum, it is difficult to take him seriously, still more when he uses a somewhat similar method to determine what kind of food is likely to agree with the operator, or the fecundity of fowls on a chicken farm. This book does not seem to be in any way a substantial contribution to the mystery of the divining rod in water finding, as so ably set forth, for example, in the work of the late Sir William Barrett.

GEOCHEMIE IN AUSGEWÄHLTEN KAPITELN. By W. J. VERNADSKY, translated from the Russian by Dr. E. Kordes. vi + 370 pp. Leipzig: Akademische Verlagsgesellschaft m. b. H., 1930.

THIS book has had a variegated linguistic career. Its earliest form was a reprint of lectures delivered in French at the Sorbonne in 1923. Three years later a revised edition appeared in Russian, and from this it has now been re-translated into German. Nevertheless, it does not read like a translation, so well has Dr. Kordes done his work. The task that the author set himself was to provide an account of certain aspects of geochemistry, with a distinct emphasis on the organic side, which he considers to have been a little neglected by other writers. The selection of the subjects, however, seems to be rather arbitrary.

The chapter on carbon and living matter constitutes nearly a third of the whole text. In this the relation of vital processes to the second law of thermodynamics is taken up, and ideas are enunciated which would scarcely commend themselves to Jeans and Eddington, for example. With regard to the part played by life in the history of the universe as a whole, the author's views are somewhat too geocentric. He is also inclined to magnify the geological importance of the works of man, which, after all, can characterize but a temporary phase in the history of the earth, and a short one at that in comparison with the whole. Here the author's sense of proportion seems to have broken down. He does not sufficiently consider how narrow are the limits of temperature and environment within which life as we know it is possible, as he should have done before questioning the validity of the general principle of increase of the entropy of the universe, leading to a final thermodynamic equilibrium when nothing can ever happen.

Throughout the book much stress is laid on the importance in geochemical processes of matter in the disperse state. It is not always quite clear what is meant by this. Apparently the reference is to the occurrence of minute traces of many or most elements in a vast variety of substances, and also to the condition of matter in the outermost layers of the atmosphere, including various kinds of radiation, and all this is associated with the distribution and geological effects of radioactive elements. It is anticipated that in the future important results will be obtained from research on these matters, but it remains rather nebulous what it is expected to lead to.

Some fifty pages are devoted to a consideration of silica and the silicates, with excursions on colloids, hydrates of iron and alumina, glauconite and the decomposition of silicates by organic agencies. This appears to be a valuable and up-to-date account of the present state of knowledge on these subjects, with many references. There is a very large Russian literature, which unfortunately is to all intents and purposes inaccessible in this country, though it is undoubtedly of vast importance, in soil-geology, for example.

The book closes with an appendix of fifty pages comprising the bibliographical references from the text, with copious explanatory notes. The author's reading has covered an enormous range in many languages, and workers in a wide variety of fields of geological research may find useful material.

La Société Géologique de France de 1880 à 1929. Par Emm. de Margerie. Extrait du Livre Jubilaire du Centenaire de la Société Géologique de France, 1830–1930.

In the introduction Monsieur Emm. de Margerie points out that the history of the first fifty years of the Society was adequately dealt with by the late Professor Albert de Lapparent, on the occasion of its jubilee. Therefore the present book is confined to a precisely similar treatment of the second fifty years. Monsieur de Margerie has himself been a member throughout the whole of this period, having actually been admitted in 1877, and he was undoubtedly the most competent authority to be found to deal with his subject. The work is divided into several sections: the work of the society; the *Bulletin*; the *Mémoires*; various publications; extraordinary meetings; the general influence of the society; statistics, and so on. Appendices contain lists of the awards of prizes and of biographical notices.

The general sections constitute an admirably condensed summary and analysis of the progress of French geology during the last fifty years. Among all this wealth of material it is invidious to pick out any one branch for special mention, but it is perhaps permissible to emphasize the special contributions of the French school of tectonics, which is so indissolubly connected with the names of Marcel Bertrand, and of de Margerie himself as the interpreter of Suess. In English-speaking countries again, no modern French geological name is better known than that of Émile Haug, while among petrologists and mineralogists Lacroix is a household word. No reference need be made here to the giants of the first fifty years, whose portraits appear in some of the twenty plates which are so conspicuous an adornment of this volume. The world owes a deep debt to France, and especially to the Geological Society of France, for their share in the scientific progress of the last hundred years, and these achievements are here worthily set forth by a master of literary style and a great geologist.

R. H. R.

JORULLO. The History of the Volcano of Jorullo and the Reclamation of the Devastated District by Animals and Plants. By the late HANS GADOW. 100 pp., with portrait, map, and 2 figures. Cambridge University Press, 1930.

THE manuscript of this book was left by Dr. Gadow almost ready for press. It has now been skilfully edited by Mr. Philip Lake and provided with a short prefatory note by Prof. A. C. Seward. The author's interests were, of course, mainly zoological, his special design being to compare this region with Krakatoa, as another devastated area. But the book contains much of interest to geologists. The point that Dr. Gadow specially emphasizes is that the first phase of the eruption of Jorullo was entirely explosive. A daily record by an eye-witness of events from 29th September, 1759, when the eruption began, to 13th November of the same year, is extant in the form of two reports sent by the Administrator of the district, Sáyago by name, to the Governor of the Province. In his diary of events Sáyago makes no mention of lava, and in reply to a special question from the Governor he states definitely that nothing flows except the sandy and ashy material that he describes. Dr. Gadow has rendered a useful service by publishing a translation of these reports, which have been rather inaccessible even in the original Spanish.

According to Ordóñez the lavas of the Malpais were the first to be erupted and afterwards the cones of Jorullo and its satellites were built up. Dr. Gadow himself thinks it probable that the great flows of lava began in 1764, when, according to tradition, the eruptive activity was at its maximum, but there is no written evidence on this point.

THE JHARIA COAL FIELD.

By C. S. Fox, *Mem. Geol. Surv. India*, vol. lvi, vii + 255 pp., with 21 plates and 13 text-figures. Calcutta, 1930. Price Rs. 8–12 or 14*s*.

THE Jharia coalfield constitutes one of the most important units of the Permo-Carboniferous coal-bearing area of India. It is situated in the east of the Chota-Nagpur division of the Province of Bihar and Orissa, mainly on the north bank of the Damuda River. As graphically described by the author, the coal-fields of the Damuda Valley represent just so many areas of Gondwana rocks set in a pavement of Archaean gneisses, and this in-setting is due to folding and faulting: all intervening formations are missing, representing an enormous lapse of time. The Gondwana rocks are wholly of terrestrial origin, though it is suggested that a sea lay to the east and south-east. This is quite consistent with the presence of the great marine Permo-Carboniferous Raub series of the Malayan area, which apparently extends northwards, at any rate into the Shan States of Burma.

Only part of the Gondwana system occurs in this field, the Rajmahal series at the top being absent. Dr. Fox believes that the Talchir boulder-bed at the base is not undisturbed morainic material, but has been worked over by water: he therefore concludes that the true Ice Age of Gondwanaland was earlier than the Talchir beds as we find them to-day. This is a point of considerable importance in connection with the exact dating of the glacial deposits of the Gondwana in all the areas where they are now extant.

A CATALOGUE OF BRITISH SCIENTIFIC AND TECHNICAL BOOKS.

3rd edition. 754 pp. London: Denny, 1930. Price 20*s*.

THE new and revised edition of this useful publication will be welcome and the British Science Guild is to be congratulated on its appearance. Naturally it is still possible to pick out a few trifling flaws; certain errors still remain uncorrected, and some items are not up-to-date. For example, it is not clear why the *Summary of Progress of the Geological Survey* for 1923 is alone selected for mention or why two different editions of Dr. Hatch's *Petrology of the Igneous Rocks* are quoted. The scarcity of capital letters makes some titles of books look rather odd: e.g. "Wollaston, T. C., *Opal, the gem of the never never,*" p. 340.

But these are trifles: the book can be strongly recommended as an indispensable addition to all scientific libraries; the range of subjects covered is very large.

WHITAKER'S ALMANACK FOR 1931. Complete edition. 960 pp. Price 6*s*.

A GLANCE at the title-page of this invaluable publication shows that it was established in 1868. One is tempted to ask, "How did the world get on before that date ?" Naturally the book does not contain much pure geology, but one page is devoted to a list of the geological systems, and discoveries of pre-historic human or supposedly human, skulls, from *Pithecanthropus* to *Sinanthropus*. In the brief descriptions of the systems it is not perhaps the happiest choice to write "Cambrian, exemplified in Wales, *Cumberland*, etc.", because the existence of Cambrian strata in that county, though highly probable, has never been definitely established. This should be modified in the next issue. Such matters as lists of University teachers, scientific societies (with addresses), and of the personnel of the Geological Survey, together with many tables of statistics, are of course of great value to geologists, as well as to other scientific workers and to editors of scientific journals.

INTRODUCTORY ECONOMIC GEOLOGY. By W. A. TARR. pp. 664, with 249 figures. McGraw-Hill Book Company Inc., New York and London, 1930. 25*s*.

PROFESSOR TARR set himself a big task in writing this book, and he has carried it out with conspicuous success. No doubt it is possible to pick holes in the accounts of some economic deposits in countries which Professor Tarr has not visited, but this is an unescapable dilemma, because in so many cases the available descriptions are inadequate or incorrect. But there do not appear to be here anything like the howlers introduced into many German text-books, for example, concerning non-German products.

To English students the author's clear and succinct accounts of the metalliferous and other economic mineral industries of his own land will be of very great value. It is most refreshing to find that the lateral secretion theory of the origin of lead-zinc ores in limestone seems to have been finally slain and buried by the Professor of Geology in the University of Missouri.

The book covers so enormous a field that it is invidious to select points for special mention : it may, however, be said that the account here given of American oil geology is very useful in presenting in a condensed form the latest developments of that vast subject. For each section of the book there is a short bibliography, by no means all American, and now and then the descriptions are enlivened by a touch of humour. Some of the illustrations are very interesting and of rather novel type.

OBITUARY.

Bernard Barham Woodward.

The subject of this notice was the son of Bernard Woodward, Royal Librarian at Windsor, and therefore a nephew of S. P. Woodward, and of Dr. Henry Woodward, the founder and first editor of this MAGAZINE. After a short business career, he became Curator of the Geological Society's museum, and in 1876 he joined the staff of the British Museum in Bloomsbury. In 1881 he took charge of the library of the Natural History Museum, then newly removed to Cromwell Road. His greatest work was undoubtedly bibliographical, in the formation and cataloguing of the vast science library at South Kensington, but he found time also for a large amount of original research. This was mainly concerned with living shells, but on several occasions he contributed papers to geological journals on the fauna of various sedimentary deposits of earlier date ; in fact, his first important publication dealt with the mollusca of the Barnwell gravels at Cambridge. He also took part in many archæological investigations. He died 27th October, 1930, aged 77.

John William Evans, C.B.E., D.Sc., LL.B., F.R.S.

By the death of Dr. J. W. Evans, British science has lost an eminent and esteemed geologist, whose record as a teacher and investigator, as an explorer and administrator, is one of consistent and devoted service to science, to industry, and to the State.

Of him as an author it may be truly said that he wrote only out of the fulness of knowledge which, grounded in study and research, was expanded and matured by long and varied experience abroad—in India, in Brazil, in Bolivia, and the Amazon basin. Substantial as is the work he actually accomplished, yet he had planned to do still more in his retirement—which began only three years ago and was, for him, wholly nominal ; his zeal for applied science took him immediately to Egypt on a geophysical investigation ; a desire to see still more of the world carried him last year to Africa, with the British Association, where his powers of endurance astonished even his younger colleagues, and sustained him during an arduous and entirely independent tour through Tanganyika. He was virtually in harness until a week before his death.

Educated at University College and the Royal College of Science, London, he was called to the Bar in 1878. Though he soon transferred from law to science, he lost none of his early zeal for social service, and continued to take an active interest in constitutional progress, being ultimately appointed a Justice of the Peace. Meanwhile (1889) he gained his first distinction in geology—the Murchison